Preliminary Analysis Report
Local Flood Protection
Salisbury Brook/Salisbury Plain River
Brockton, Massachusetts

November 1989

US Army Corps of Engineers
New England Division

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I. Introduction

A. Study Authority

As a result of the Water Resources Development Act of 1986 (WRDA '86), the new England Division of the U.S. Army Corps of Engineers has investigated periodic flooding of the inland waterways known as Salisbury Brook and Salisbury Plain River in the City of Brockton, Massachusetts. WRDA 1986, also known as Public Law 99-662, provided pre-construction authorization to carry out the planning, engineering, and design elements for a flood control project to protect the city of Brockton, Massachusetts (see Plate 1 for Project Vicinity Map). The article specifically states the following regarding the Brockton project:

> Flood control works for the protection of Brockton, Massachusetts, at a total cost of $1,500,000. The plans for such project shall include, but not be limited to, improvements to ponds in the D. W. Field Park area and the existing Brockton-Avon Reservoir to provide additional storage, improvements to the drainage system under E. B. Keith Field, new culverts, improvements to miscellaneous bridges and utilities, and such other downstream improvements as the Secretary deems necessary.

B. Study Objective

The purpose of this report is to determine a feasible flood control plan for the frequently flooded areas along the Salisbury Brook and the Salisbury Plain River in Brockton.

C. Study Area Description

The city of Brockton, Massachusetts is located approximately 18 miles south of Boston and 25 miles northwest of Providence, RI. See Plate No. 1. The Salisbury Plain River and its main tributaries, Salisbury Brook and Trout Brook drain the central and southernmost areas of the city.

The area flood insurance study prepared by the U.S. Department of Housing and the Urban Development for the City of Brockton, Massachusetts, September 1978, shows downstream flood profiles on the Salisbury Plain River reach acceptable levels in the vicinity of the Meadow Lane bridge for all postulated floods. This location shall define the downstream limit of the study area. Above that point the Salisbury Plain River Basin comprises an area of 16.4 square miles with portion located in the towns of Avon, Holbrook and Stoughton as well as Brockton. The study area watershed is depicted in Plate 2.

The upper part of the watershed area is drained by Beaver Brook which flows into a series of ponds that are part of the D.W.Field Park: Brockton Reservoir, Waldo Lake, Upper Porter Pond, Lower Porter Pond, Thirty Acres Pond, Ellis Brett Pond, and cross Pond. Lovett Brook drains the westernmost portion of the watershed, and its flow joins the above progression at Ellis Brett Pond.

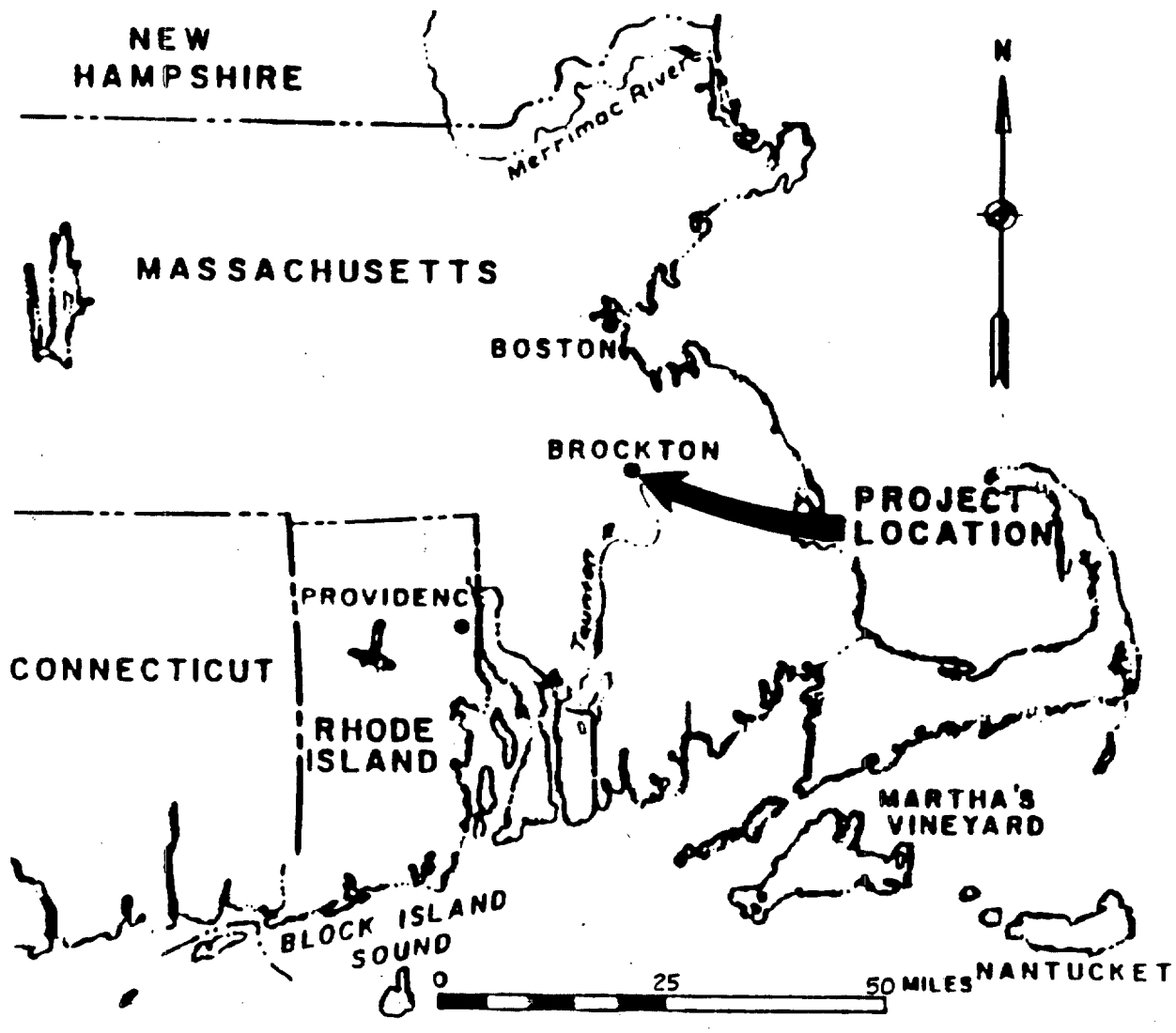
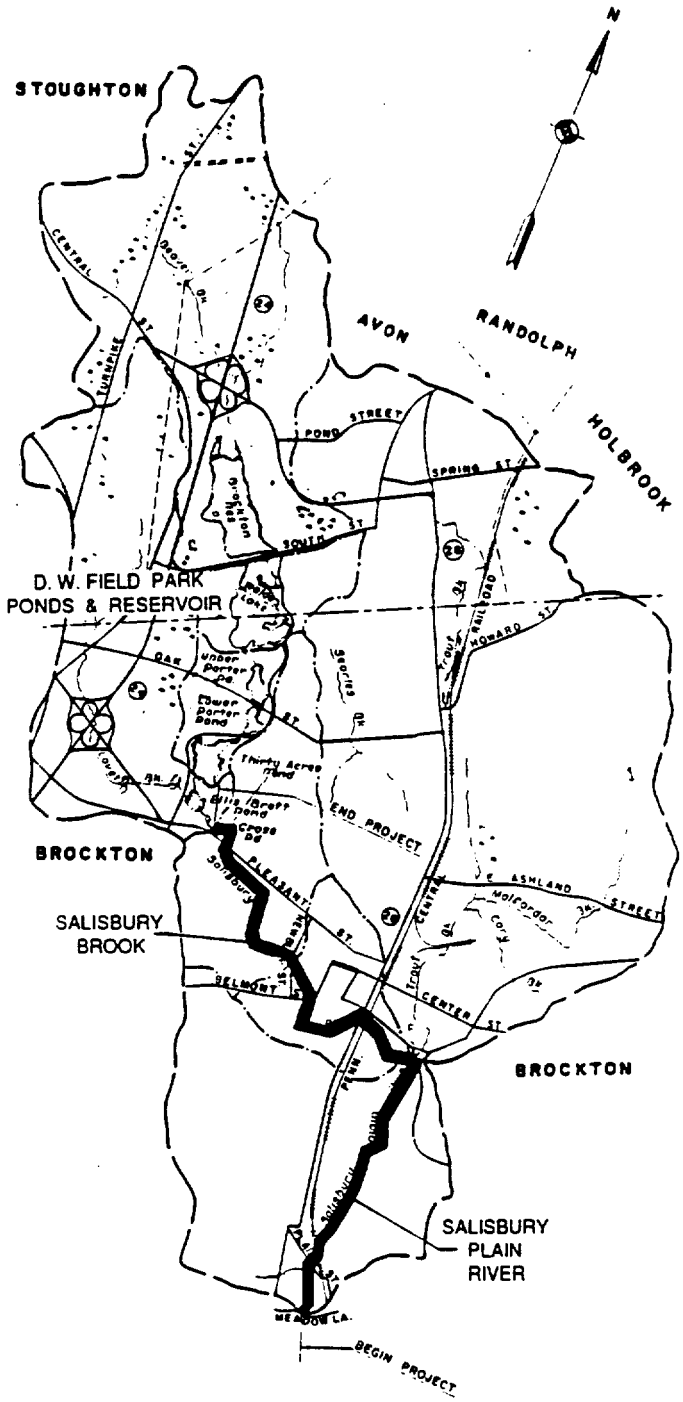


PLATE 1

Project Vicinity Map

New England Division

US Army Corps
of Engineers



DRAINAGE AREA MAP

PLATE 2

Salisbury Brook / Salisbury Plain River

BROCKTON , MASSACHUSETTS

New England Division

US Army Corps of Engineers

From the Cross Pond outlet, the Salisbury Brook flows in a general southeasterly direction through Brockton's west side. In 2.6 miles it joins Trout Brook to become the Salisbury Plain River just southeast of the Brockton central business district.

The Salisbury Plain River begins 180 feet west of the intersection of Grove Street and Pine Street in Brockton at the confluence of Salisbury Brook and Trout Brook and flows due south to the West Bridgewater town line.

Restrictive channel characteristics, accelerated development of adjacent land, and a lack of channel maintenance have combined to produce frequent flooding along sections of Salisbury Brook and Salisbury Plain River.

D. Prior Corps Involvement

In 1975 the Corps of Engineers proposed a plan that was prepared by Fenton G. Keyes associates of Providence, Rhode Island. This plan consisted of a series of improvements intended to provide 100-year flood protection for the areas along Salisbury Brook and the Salisbury Plain River.

Among the measures proposed for Salisbury Brook were new bridges at Pleasant Street, Ash Street, and Belmont Avenue; installation of flood walls from Ash Street to Spring Street; new culverts along Ellsworth Street and beneath the Brockton YMCA parking lot; removal of channel obstructions upstream from Prospect Street and Moraine Street; modification of the channel invert near the entrance to the culvert under the Eldon B. Keith Athletic Field; a cap for the retaining walls downstream from Warren Avenue; and relocation of numerous utilities that are presently beneath bridges.

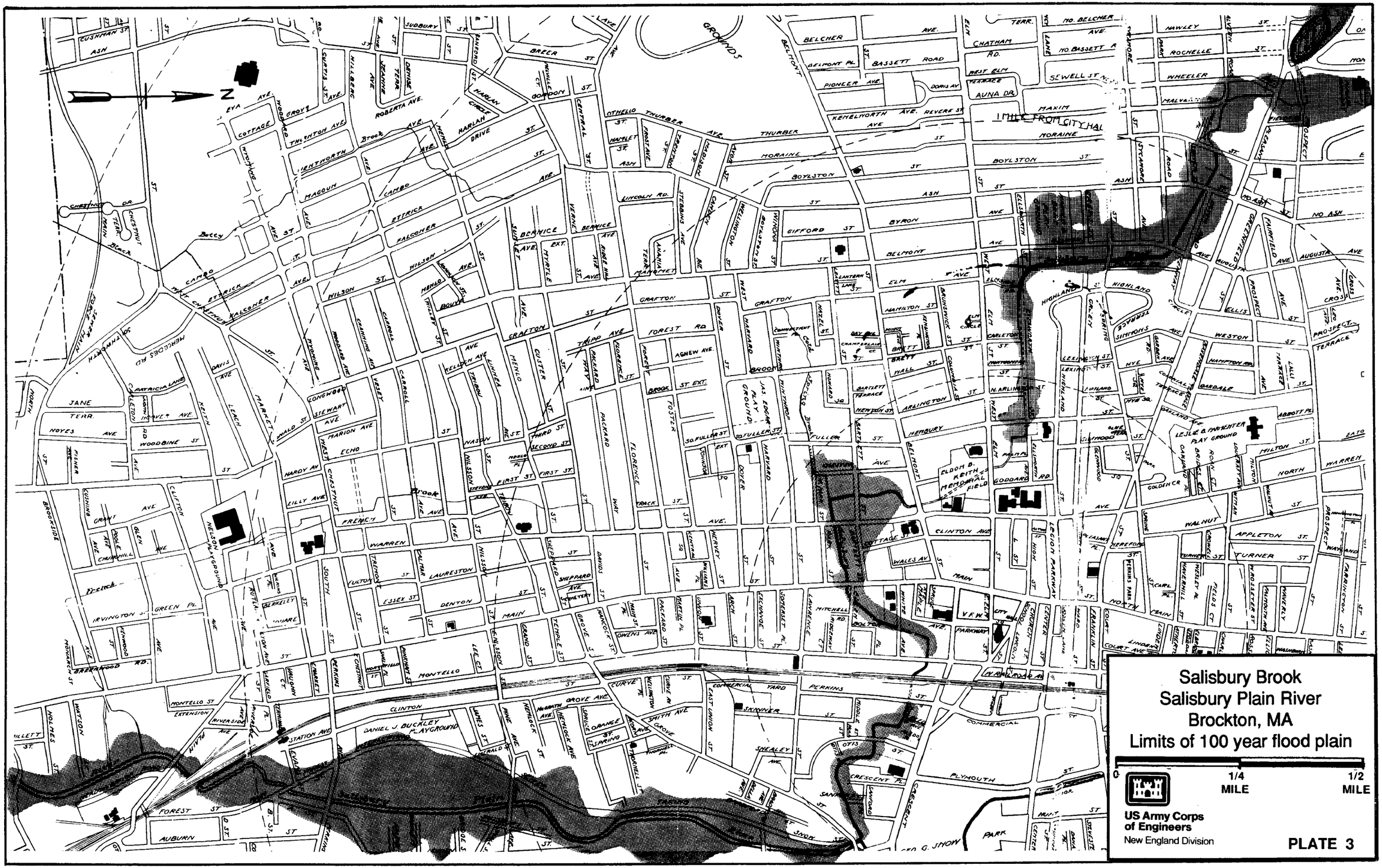
Improvements along the Salisbury Plain River included construction of dikes upstream from Perkins Avenue and floodwalls between Perkins Avenue and Forest Street, extensions or caps would be added to existing retaining walls at various locations, and utilities would be relocated from beneath several bridges.

However, the 1975 plan was found not to be economically justified. The computed benefit-cost ratio of 0.2 precluded further Federal involvement.

E. Ongoing Study Area Projects

The city of Brockton has begun a program of bridge work that has prioritized the downstream areas of the Salisbury Plain River. A new bridge is in place at Plain Street and bridge relocation is underway at Meadow Lane. Other bridges selected for the next phase of improvements are: Perkins Avenue, Center Street (at Trout Brook), Main Street and Bartlett Street (at Salisbury Brook). These further projects will be accomplished as state and local funds become available.

Recently, some attempts have been made to reduce flash flooding along Lovett Brook. Ellis Brett Pond, where Lovett Brook enters the study area, was the location of a local project completed during the summer of 1988. Most of the time the pond area is dry, and a narrow deepened channel carries


1 MILE FROM CITY HALL
Salisbury Brook
Salisbury Plain River
Brockton, MA
Limits of 100 year flood plain
0
1/4 MILE
1/2 MILE
US Army Corps of Engineers
New England Division
PLATE 3


1 MILE FROM CITY HALL
Salisbury Brook
Salisbury Plain River
Brockton, MA
Limits of 20 year flood plain
0
1/4 MILE
1/2 MILE
US Army Corps of Engineers
New England Division
PLATE 4

the Lovett Brook and Thirty Acre Pond inflow across the pond area to the outlet. In an effort to retard flow, the city authorized a local contractor to modify this channel by creating a zig-zag path for the flow to follow across the pond area. Consequently some material was removed in the course of this work and some retardation of flow as well as a slight increase in storage capacity at Ellis Brett Pond may be realized. In addition, developers have built several small retention ponds along Lovett Brook. One is located upstream of Ellis Brett Pond and just west of the park boundary and another is south of Route 27 across from the Westgate Mall main entrance.

II. Problem Identification

A. Flood History

Of the many floods recorded in the study area over the years, the floods that occurred in August 1955, March 1968, and March 1969 are considered to be the three most significant events in terms of flood level, duration, and damages. The 1955 storm represents the record rainfall for the area and may be equated with a 100-year flooding event in Brockton. Table 1 depicts the estimated peak discharges associated with those three storms at three study area locations.

Table 1
Estimated Peak Discharges (cubic feet per second)

Event	Salisbury Brook at Belmont Avenue	Trout Brook at confluence with Salisbury Brook	Salisbury Plain River at Perkins Avenue
1955 Flood	800	650	1500
1968 Flood	330	300	640
1969 Flood	450	350	820

B. PROBLEM AREAS

Salisbury Brook

On Salisbury Brook the channel streambanks are characterized by both floodwalls and earth banks. Channel widths vary from 12 to 25 feet. The channel is constricted by sediment deposits, trash and vegetation.

Upstream development has further taxed the channel's limited capacity. A considerable portion of that development lies along Lovett Brook within two miles of Cross Pond. Runoff from these areas can quickly enter the system and consequently flood stages can reach top of bank elevation much sooner than they had in the past.

Comparisons of file photographs from the early 1970's with some that were taken recently reveal a significant increase in both the size and the quantity of streamside vegetation. Interviews with abutters of the waterway suggest an increasing frequency of nuisance flooding events.

Aside from suspended utilities beneath many of the bridges and numerous trees in or near the channel, the following physical constrictions are adversely affecting the flow of Salisbury Brook. Just upstream of the Prospect Street bridge a concrete foundation and slab effectively reduce the channel capacity.

The bridge opening at Pleasant Street (Route 27) is sized inadequately to admit the high downstream flows. At present this feature causes backwater to inundate a small wetland area north of Prospect Street.

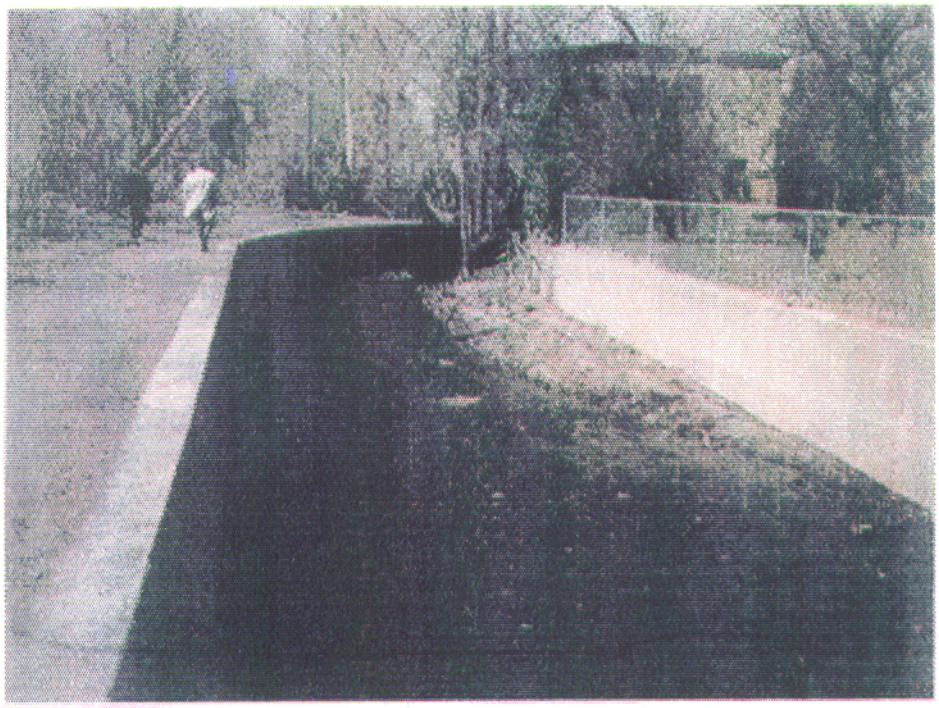
Just upstream from Moraine Street a concrete box culvert exists with only a 56 square foot opening. Only very low water levels pass without restriction. At higher stages this structure may be directly responsible for the earliest overbank flooding. Downstream from both Belmont Avenue and Spring Street private fences encroach upon the channel. These fences can trap floating debris and act as partial dams.

Downstream of Newbury Street the flow of Salisbury Brook suffers from problems with the alignment of the channel. A 90 degree bend, over which a private garage exists, creates a constriction that causes high flows to back up above this point. Larger debris transported by the brook will tend to be caught at the bend. Just around this bend Salisbury Brook enters the rectangular culvert that runs from the courthouse parking lot under West Elm Street and the E.B. Keith Athletic Field. Here, the channel invert elevation outside of the culvert opening is 2.5 feet higher than the floor elevation inside.

Behind the Brockton YMCA a parking area exists on a concrete deck over the channel. Due to the low bank elevation and the presence of the deck, flooding occurs at this location.

Salisbury Plain River

On the Salisbury Plain River the channel widths are greater than on Salisbury Brook. Earth banks characterize a generally undeveloped flood plain area from Grove Street to Perkins Avenue. Between Perkins Avenue and Forest Street a combination of higher banks and partial coverage with floodwalls defines the route of the river through an industrial complex. The locations of five firms abut the river channel, and several others nearby are within the identified 100-year flood plain. At Forest Street, however, a transition is made to concrete floodwalls intended to protect the adjacent industries. The bridge opening at Perkins Avenue is undersized due to projecting abutments and suspended utilities. High flows from upstream back up here. Inconsistent elevations and gaps in the floodwalls downstream admit floodwaters into the remainder of the industrial area. The alignment of the Salisbury Plain River in the industrial area features several bends. The



SALISBURY BROOK
LOOKING UPSTREAM FROM OTIS STREET, MARCH 1971
NOTE THE ACCUMULATION OF SEDIMENTS ON THE INSIDE OF BEND AND THE YOUNG TREES.

SALISBURY BROOK
LOOKING UPSTREAM FROM OTIS STREET, MAY 1988
NOTE THE INCREASED AMOUNT OF SEDIMENTS ALONG THE BASE OF THE WALL AND THE MATURE TREES.

wider channel in combination with these bends encourages alluvial deposits of trash and silt when the moving water is slowed in this vicinity. Beyond the industrial area the Salisbury Plain River passes beneath a stone arch railroad viaduct before reaching the bridges at Plain Street and Meadow Lane at the limits of the study area. New development occurring between Plain Street and the city limits promises to make this an important area to monitor in the future.

C. Public Involvement

Early recognition of the need for considerable public involvement was made for the Salisbury Brook/Salisbury Plain River Study.

Meetings were held on February 26, 1988 and April 26, 1988 in which local, State, and Corps officials identified problems, produced a scope of work, and discussed funding prerequisites and possibilities. City officials agreed to assist the Corps in gathering data both historical and current in support of the reconnaissance effort. NED representatives had prepared a cost estimate for the project's feasibility phase, and the Commonwealth of Massachusetts Department of Environmental Management, Division of Waterways pledged to assist the City of Brockton by providing fifty percent of their share. On May 2, 1988 Mayor Carl Pitaro provided the Corps with a letter of intent to participate in feasibility cost sharing. See Item 2 of Appendix A.

A lack of sufficient benefits had resulted in no Federal participation in previous reconnaissance studies. Given the high percentage of development that existed in the study area at the time these previous studies were conducted, increases to benefits would be required for homes, businesses and institutions that were included in the old flood damage surveys. A public meeting was held on June 30, 1988 at the Brockton City Hall. This meeting provided an opportunity for concerned citizens to present accounts of flood damages that they had experienced.

Upon completion of the cost estimates for project alternatives and the area's economic studies, a meeting took place on October 24, 1988. A summary of the Corps' findings was presented to city and state officials at that time.

III. PLAN FORMULATION

A. Without Project Condition

Without implementation of flood control measures, the recurrence of losses similar to those documented along Salisbury Brook and the Salisbury Plain River during the last thirty-five years is expected to continue. Without a timely cleanup effort and a channel maintenance program those losses may increase in both frequency and severity. Land use patterns and real estate values are not expected to change significantly within the flood plain areas.

B. PLAN 1, Updated Corps Plan from 1975

The comprehensive plan for flood protection that was developed by the Corps in 1975 was updated and re-examined as an alternative in 1988.

The elements of the plan are as follows:

- -new bridges at Perkins Avenue, Belmont Avenue, Ash Street, and Pleasant Street
- -new box culverts at the YMCA parking lot, and two locations along Ellsworth Street
- -floodwalls from Perkins Avenue to Forest Street, and from Ash Street to Spring Street
- -dikes upstream from Perkins Avenue
- -demolish concrete decks upstream from Moraine Street and Prospect Street
- -remove all trees greater than 6" diameter from streambanks between Plain Street and Meadow Lane
- -relocate all utilities from beneath bridges

Certain project elements from 1975 are no longer included in the plan. For example, downstream from Forest Street a building over the channel was slated for removal in 1975. That has since been accomplished. A small footbridge near the same location will be retained, however, as it is essential to the operation of the adjacent industry. New bridges at Plain Street and Meadow Lane have eliminated restrictions due to small openings and suspended utility pipes at those locations.

In 1975 the plan's design features were intended to provide up to 100-year flood protection for the areas adjacent to Salisbury Brook and Salisbury Plain River. An updated hydrology, however, indicates that the same plan in 1988 would be effective up to only 75 years. Among the reasons for this diminished effectiveness are increased vegetation and sedimentation in the channel along with slightly increased peak flows predicted by the hydrology.

SALISBURY BROOK
CONCRETE CULVERT UPSTREAM
FROM MORAINE STREET.
THE RESTRICTED OPENING CAN
SCARCELY ADMIT NORMAL
STREAMFLOWS.

SALISBURY BROOK
LOOKING UPSTREAM FROM BELMONT AVENUE.
CLOSE PROXIMITY OF STRUCTURES TO THE CHANNEL
IS NOT AN UNUSUAL OCCURRENCE.

Directly affected by the upward spiral of nationwide construction costs, the estimated cost of the project is now $5.7 million as opposed to $2.3 million when assessed in 1975. Unfortunately, estimated annual benefits throughout the study area have not kept pace with these rising construction costs. Annual benefits were estimated at $53,200 including emergency costs of $11,400. The overall benefit to cost estimate ratio for Plan 1 is 0.1. This very low value compares unfavorably to even the 1975 figure of 0.2. The updated Corps Plan, therefore, lacks economic justification.

C. PLAN 2, Increased Storage Capacity of Ponds and Miscellaneous Channel Improvements

The upstream water resources located in D.W. Field Park were investigated for their potential flood control contributions. The series of ponds within the park constitute the principal storage area in the upper watershed with downstream flow regulated by a circular outflow structure at Cross Pond. Aesthetically pleasing stone outlet structures are characteristic of the ponds located with D.W. Field Park. An earth dam featuring a pumphouse and spillway forms the southern end of the Brockton-Avon Reservoir, which is fed by Beaver Brook at the upper extreme of the watershed. Waldo Lake is used for public water supply, and the Brockton-Avon Reservoir is scheduled to be reinstated for that purpose in the fall of 1989. A principal contributor to the downstream flow along Salisbury Brook is Lovett Brook, the flow of which enters the chain of ponds from the west side of Ellis Brett Pond.

Increased storage capacity at the ponds combined with an active management of modified control structures was envisioned as a partial solution to downstream flooding problems. Potential benefits from an increased water supply also made the concept of flood control measures in the park area particularly attractive. The plan formulation for any project alternative in this area must be sensitive to the established scenic quality of this park land as well as water quality, animal habitat and public access issues.

Because of adverse visual impacts and possible compromised public access, the concept of increased storage by building walls or dikes was abandoned. Throughout the park only a small amount of freeboard is available at each pond so only modification of the weirs at the control structures was considered. With this limitation, only a small amount of additional storage could be obtained. Benefits from increased upstream storage would therefore be limited. Hydrologic analysis provided a more compelling reason to abandon this alternative: peak flows from Lovett Brook account for ninety-five percent of the discharge at the Cross Pond spillway; storage areas above Ellis Brett Pond would only control five percent of the discharge at that point. Therefore, no significant reduction of downstream flooding can occur as a result of a project centered on the upper ponds. As soon as the lack of effectiveness for flood control was established, further developement of this alternative was curtailed. Information on the physical characteristics of these ponds appears in Table 2.

Table 2
Pertinent Data on Storage Areas within D.W. Field Park

Ponds	Drainage Area (sq. mi.)	Surface Area (acres)	Storage Capacity Per Foot of Surcharge (inches)	Total Surcharge to Top of Dam (feet)	Discharge Capacity 1 Foot Above Spillway (cfs)
Brock. Res.	3.0	101	0.63	4.0	75
Waldo Lake	3.2	75	0.44	3.5	40
Upper Porter	3.3	11	0.05	3.0	60
Lower Porter	3.3	8	0.04	3.0	60
Thirty Acre	3.8	26	0.13	3.0	60
Ellis Brett	5.9	5	0.03	-	27
Cross Pond	5.9	1	0.01	2.5	160

D. Plan 3, Tunnel By-Pass with Miscellaneous Channel Improvements

The third alternative that was investigated is construction of a by-pass culvert that would carry the flow of Salisbury Brook from a point about 600 feet downstream from Pleasant Street to the vicinity of the E.B. Keith Athletic Field. This culvert would be constructed using a cut and cover form of construction and would follow mostly public rights of way. Plate 5 shows a preliminary profile of the by-pass culvert. Diverted flows would run south under Malvern Road, east under Sycamore Street and Sycamore Avenue, south under Ash Street and east under the Harold Bent Playground. At Belmont Avenue the culvert would again turn south and follow Belmont Avenue to West Elm Street. Here, a deeper excavation would be required to maintain the slope of the culvert. That greater depth would gradually diminish as the culvert followed the West Elm Street right of way east to its junction with the existing Salisbury Brook culvert beneath the E.B. Keith Athletic Field. In addition to the by-pass culvert, this alternative would include dikes and flood walls to protect the industrial area near Perkins Avenue.

The estimated size of the by-pass culvert would be eight feet by nine feet. The implementation of the by-pass would involve considerable relocation of utilities beneath the streets named above. No major relocation of the athletic facilities at the Harold Bent Playground would be required as a right of way between the existing tennis and basketball courts can be utilized. The cost estimate for the culvert alone is $6.45 million, which excludes utility relocations and any real estate costs.

While this plan could provide relief for residents of the Moraine Street, Ash Street, Belmont Avenue, and Ellsworth Street areas for up to the 100-year flood event, the cost associated with the by-pass culvert item alone is prohibitive when compared to the benefits computed for the protected homes in these neighborhoods. Therefore, the tunnel by-pass plan was dropped from further study.

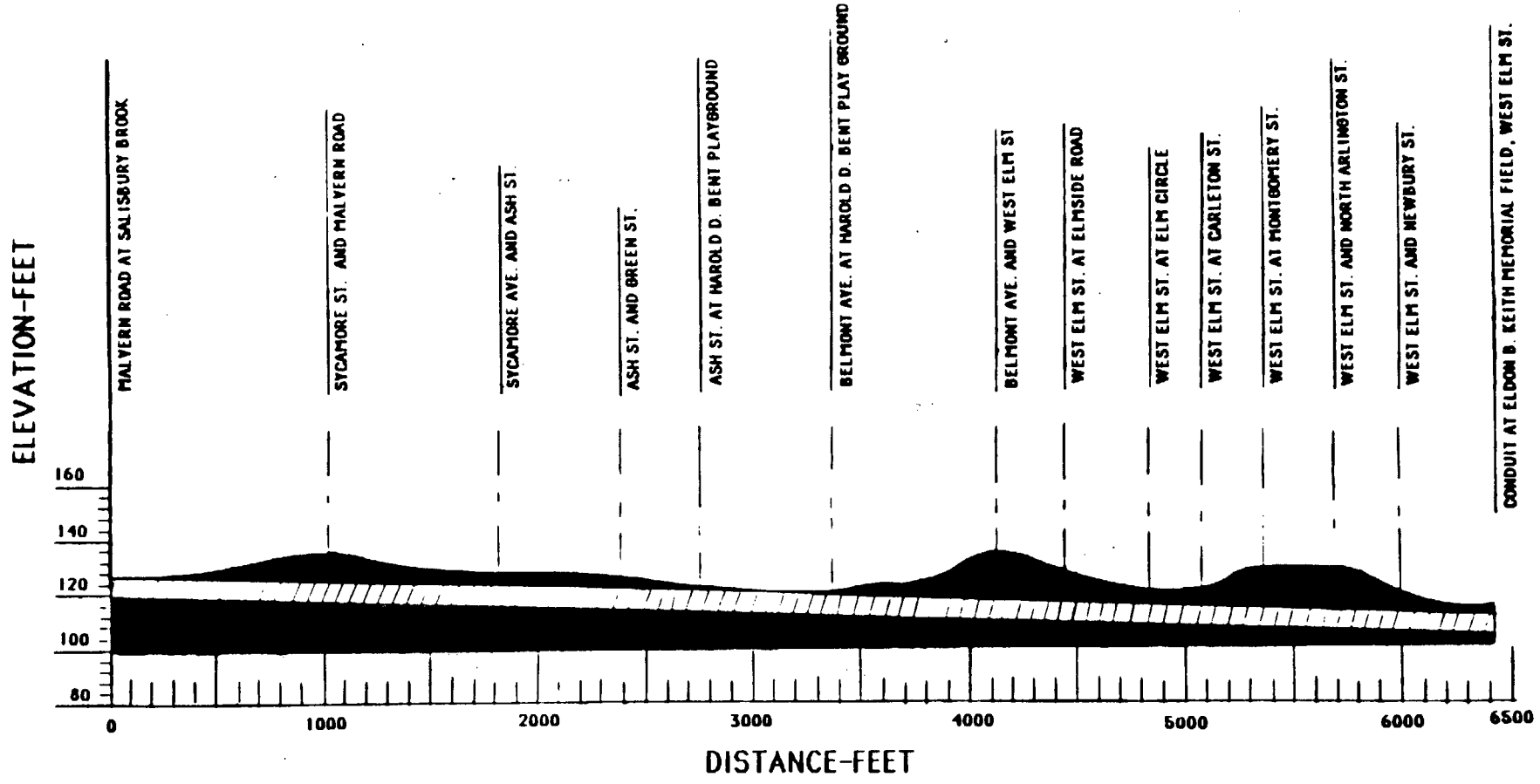


PLATE 5

CONDUIT FROM MALVERN ROAD AT SALISBURY BROOK
TO ELDON B. KEITH MEMORIAL FIELD, WEST ELM STREET

PROPOSED CONDUIT SIZE - 8' x 9'

LOCAL PROTECTION PROJECT
SALISBURY BROOK
&
SALISBURY PLAIN RIVER
BROCKTON, MASSACHUSETTS

PLAN 3 - TUNNEL BY-PASS PROFILE

E. PLAN 4, 20 Year Selective Protection Program

The comprehensive plan that the Corps developed in 1975 was designed to provide a 100-year level of protection for the residents and businesses within the Salisbury Brook/ Salisbury Plain River watershed area. Although benefits due to flood damage reduction were not sufficient for this plan to be adopted, this prior study allowed us to identify several reaches where the maximum benefits could be obtained. Salisbury Brook from Elmwood Avenue to Spring Street and Salisbury Plain River from Pine Street to Plain Street are two zones where the highest annual benefits were identified.

In an effort to maximize annual benefits a fourth plan was formulated to provide protection within just these zones. Not only was a selective protection plan prescribed but a reduced level of protection was tried as well.

Recognizing that Plan 1 represented approximately 75-year flood protection, a 50-year plan was judged to be too similar; hence, the 20-year plan was chosen.

This plan consists of similar measures as were proposed for Plan 1 albeit scaled down to the 20-year flood elevation plus freeboard.

In the west side residential area, floodwalls would be installed from Ash Street to Spring Street. A concrete-lined channel would be built downstream from Newbury Street extending to the existing conduit opening at the rear of the courthouse parking lot. Channel shape and invert elevation would be adjusted to maximize the efficiency of flow into the conduit entrance. Upstream of Perkins Avenue dikes would provide protection to elevation 80.0'. In the industrial area between Perkins Avenue and Forest Street new floodwalls would be built to that same elevation except for areas where existing walls would be capped. Downstream from Forest Street the retaining walls would have to be restored at several locations.

The lined channel would reduce backwater effects from the restrictive conduit opening and the floodwalls and dikes would provide the limited protection to the areas named above.

This plan was conceptualized to feature a lower cost than the other structural flood control alternatives while maximizing benefits. Although it proved to be the least expensive structural alternative at $3.4 million, the annual cost dramatically outweighed the projected benefits. The benefit to cost ratio is 0.04 which reflects again today's high construction costs. While Plan 4 would provide some relief from flooding to two of the hardest hit areas it is clear that the costs of implementing an effective flood control project along Salisbury Brook and Salisbury Plain River exceed currently available benefits.

F. Plan 5, Non-Stuctural Measures

Non-structural flood control alternatives are those measures or combinations thereof that do not include the construction of separate flood control works such as dams, flood walls, lined channels, and dikes.

The Salisbury Brook/Salisbury Plain River flood plain is characterized by older structures. Basement flooding of these areas may mean above average costs to repair to antiquated plumbing and heating systems. Some non-structural measures were introduced as possibilities to apply to homes within the flood plain. Construction of internal or external utility cells to house heating equipment, raising existing structures on their foundations, and public acquisition of flood plain land were some of the measures considered. Because these measures apply to individual structures, the number of structures located in the flood plain and their respective first floor elevations become prime determinants of the cost and appropriateness of each alternative.

Typical costs for non-structural measures are estimated to be as follows:

a) construct utility cells (to house heating unit, h.w. heater, breakers)	$30,000/house[1]
b) raising existing structures (on foundations)	$27,000/house[2]
c) construct ring walls around individual structures	Costs of individual installations will exceed the cost of Plan 1, floodwalls in these zones.
d) public acquisition of flood plain land (includes moving cost)	Market value is significantly greater than a), b), or c).

To check the feasibility of these non-structural methods of flood damage prevention, consider the raising of existing structures, and apply it to sixty percent of the total of eighty homes that are within the 100-year flood plain for the zones between Elmwood Avenue and Spring Street. Estimated cost for such a program would be:

(0.60) x (80 homes) x ($27,000/home) = $1,296,000.

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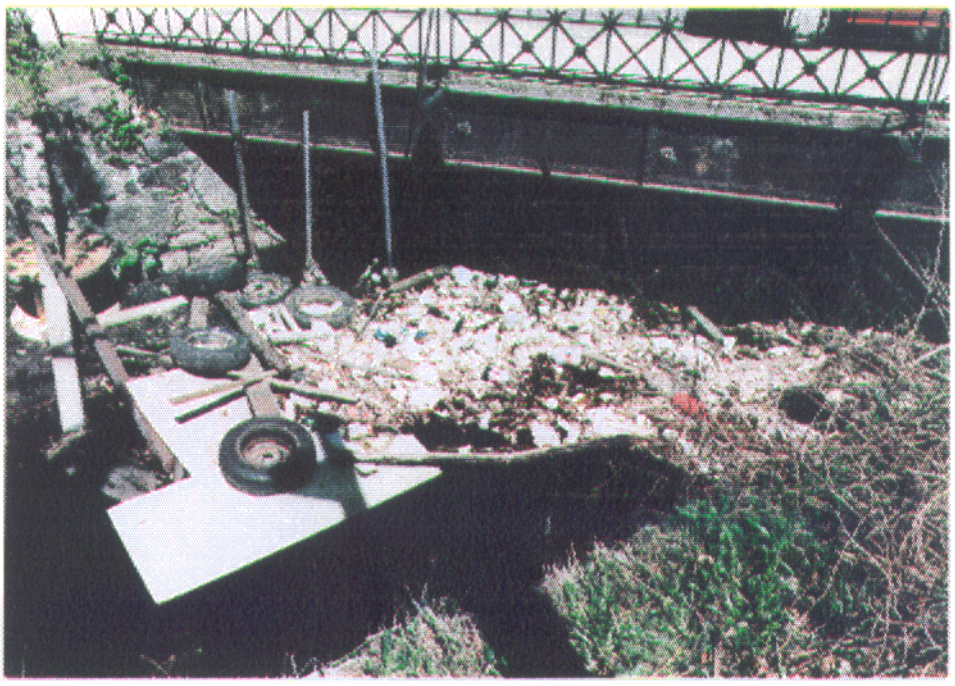
1 New England Division experience with Belmont Park (RI) project in 1985 suggests this as a minimum figure.

2 Tidal - Flood Management West Central Connecticut - U.S. Army Corps of Engineers, New England Division, June 1988, p.C-10. (Assume single family home 40x24, cost to raise a home is $28/ft2, 40'x 24'x $28/ft2= $27,000.

SALISBURY BROOK
ENTRANCE TO BOX CULVERT BEHIND COURTHOUSE ON WEST ELM STREET. FROM THIS POINT THE FLOW CONTINUES BENEATH THE COURTHOUSE PARKING LOT AND THE E. B. KEITH ATHLETIC FIELD.



SALISBURY BROOK
A SIGNIFICANT AMOUNT OF DEBRIS HAS ACCUMULATED BENEATH THE ALLEN STREET BRIDGE IN THIS PHOTO TAKEN MAY 4, 1988.

Assume that benefits would be equal to those for Plan 1 in the same zones (Elmwood Ave., to Spring St.); use $8,200.[3] If the project had a fifty year life, the non-structural program would have a minimum annual cost of:

($1,296,000) x (0.09003)= $116,700

For the residential areas, therefore, a typical benefit to cost ratio would be $8,200/$116,700 = .07. For many of the firms that are located in the industrial areas, the pumping of seepage and floodwaters from their basements has become routine. While most precautions have been taken to minimize losses the continued presence of moisture in these buildings poses a threat to computer systems and other specialized hardware that is in use. For floodproofing to be effective considerable expense will be incurred on these generally older structures. A typical installation might include a floor and wall sealant such as gunnite and/or a vapor barrier to retard transmission of moisture to the upper stories. Because most of these industrial buildings are in close proximity to the channel, these costly flood-proofing measures are effective only for the higher frequency storms. For greater than 80-year storms some of the buildings will suffer first floor flood damages. More sophisticated items such as continuous gasket door and window seals would be required to prevent damage in these instances. However, the costs associated with basement sealing alone were found not to be economically justified. For example, the cost of basement floodproofing of the King Size and former New England MacIntosh buildings located just downstream from Perkins Avenue were estimated to be a total of $465,000[4]

Annual costs for basement floodproofing of these structures alone would be about $42,000[5] while the annual benefit computed for a 75-year level of protection in those zones from Grove Street to Plain Street is about $28,000. Clearly, when the additional industrial properties in the area and the Walkover Club are also considered, a limited flood proofing program cannot be justified.

G. PROJECT ECONOMICS

Earlier studies by the Corps included damage area inspections in response to some of the more severe high water events in Brockton, and the subsequent development of a detailed flood damage survey for the study area. Because of the already high percentage of development in the study area it was only necessary to update the existing flood damage survey to account for limited new construction and changes in land uses. Topographic information and the first floor elevations of structures remained essentially as recorded for the 1975 study. Flood damage information gathered with the assistance of the

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[3] See Table 5 on page 13.

[4] Estimating Costs and Benefits for Nonstructural Flood Control Measures,
William D. Carson, The Hydrologic Engineering Center
U.S. Army Corps of Engineers October 1975
From Table A-8 use costs for 90,000 ft^2 and 65,000 ft^2, the latter extrapolated from the "Large 2" and "Large 3" entries. =465,000

[5] Based on 50 year project life, ($465,000)x(0.09003) = $42,000.

city was organized to supplement the flood damage survey compiled in 1975. For the economic analysis, the study area along Salisbury Brook and Salisbury Plain River was divided into five sub-areas: Elmwood Avenue to Spring Street, Spring Street to Bartlett Street, Bartlett Street to Grove Street, Grove Street to Plain Street and Plain Street to Meadow Lane.

Annual losses due to flood damages are presented below for each of these sub-areas. Annual losses were estimated by combining recurring losses (stage/damage data) with hydrologic stage frequency data. The damage zones in the table below are grouped to coincide with the stage-frequency curve that applies to that specific section of river.

Table 3
ANNUAL LOSSES
(Oct. 1988 Price Level)

ZONE	ANNUAL LOSSES
Salisbury Plain River:	
Plain St to Meadow Ln	$ 8,800
Grove St to Plain St	73,400
Salisbury Brook:	
Bartlett St to Grove St	11,400
Spring St to Bartlett St	9,800
Elmwood Ave to Spring St	14,200
Emergency Costs	31,600
TOTAL	$149,200

Recurring losses for selected flooding events were calculated along both Salisbury Brook and Salisbury Plain River. Recurring losses are those potential flood related losses which are expected to occur at specific stages of flooding under present-day development conditions. Losses in the study area for various flooding events are found in Table 4 below.

Table 4
Recurring Losses
(Oct. 1988 Price Level)

ZONE	10 Yr	20 Yr	50 Yr	100 Yr	500 Yr
Salisbury Plain River					
Grove St - Meadow Lane	$12,100	$339,600	$1,166,900	$2,312,600	$4,570,300
Salisbury Brook					
Elmwood Av - Grove St.	37,100	82,200	209,500	586,900	3,311,000
TOTAL	$49,200	$421,800	$1,376,400	$2,899,500	$7,881,300

Annual benefits for the candidate plans were computed for each of these sub-areas where applicable. All benefits and losses are calculated to an October 1988 price level. Annual loss and annual benefit data as well as benefit/cost ratio computations follow for Plans 1, 3, and 4.

Plan 1, designed to provide a 75 year level of protection (1.3% chance of annual occurance) would include 4 new bridges, 3 new culverts, floodwalls from Ash St. to Spring St., floodwalls from Perkins Ave. to Forest St., dikes upstream of Perkins Ave., removal of several channel obstructions, and relocation of numerous utility pipes at an estimated first cost of $5.7 million.

Table 5
Annual Losses, and BCR Computation for Benefits for Plan 1,
Comprehensive Flood Protection

	ANNUAL LOSSES		
	Natural	Modified	ANNUAL
ZONES	(w/o project)	(w/project)	BENEFITS
Plain St/Meadow Ln	$ 8,800	$ 4,800	$ 4,000
Grove St/Plain St	73,400	45,600	27,800
Bartlett St/Grove St	11,400	9,800	1,600
Spring St/Bartlett St	9,800	9,600	200
Elmwood Av/Spring St	14,200	6,000	8,200
Emergency Costs	31,600	20,200	11,400
TOTAL	$149,200	$96,000	$53,200

Annual Benefits = $53,200
Annual Cost = $501,000
Benefit/Cost Ratio = 0.1

Plan 3 features a 9' x 8' by-pass culvert from the Malvern Rd. area to E.B. Keith Field with dikes upstream of Perkins Ave. and floodwalls from Perkins Ave. to Forest St.

As proposed, it could provide 100 year level of protection for the residential areas (1.0% chance of annual occurrance) at an estimated first cost of $6.8 million.

Table 6
Annual Losses, Benefits, and BCR Computation for Plan 3,
Tunnel By Pass with Miscellaneous Channel Improvements

ZONE	ANNUAL LOSSES Natural (w/o project)	Modified (w/project)	Annual Benefits
Pleasant St/Belmont St	$14,800	$ 3,400	$11,200
Perkins Ave/Plain St	73,400	45,600	27,800
TOTAL	$88,200	$49,000	$39,000

Annual Benefits = $39,000
Annual Cost = $598,500
Benefit/Cost Ratio = 0.1

Plan 4 would proide a 20-year level of protection to selected areas. Improvements would include floodwalls from Ash St. to Spring St., a lined channel and lowered invert downstream from Newbury St., dikes upstream from Perkins Ave., and floodwalls from Perkins AVe. to Forest St. at an estimated first cost of $3.4 million.

For Plan 4, benefits were estimated for protection of three specific areas up to the 20-year event. Benefits for 50 percent of freeboard were included where appropriate.

SALISBURY PLAIN RIVER
LOOKING UPSTREAM TOWARD THE FOREST STREET BRIDGE.
THE CHANNEL WIDTH AND ALIGNMENT ENCOURAGE ALLUVIAL DEPOSITS IN THE AREA.

SALISBURY PLAIN RIVER
LOOKING DOWNSTREAM TOWARD RAILROAD SIDING
THAT SERVICES THE INDUSTRIAL AREA.

Table 7
Annual Losses, Benefits, and BCR Computation for Plan 4,
20-Year Protection in Selected Areas

AREA	ANNUAL LOSSES Natural (w/o protection)	Modified (w/20-yr prot.)	Annual Benefits[6]
Perkins Ave, Pine Ave/Conrail Siding	$34,100	$24,100	$10,000
Newbury St/West Elm St Carleton St	6,100	5,100	1,000
Ash St, Belmont Ave, Spring St	7,000	3,000	4,000
TOTAL	$47,200	$32,200	$15,000

Annual Benefits = $15,000
Annual Costs = $260,800
Benefits/Costs Ratio = 0.06

The annual benefit values from these tables are compared with annualized construction cost estimates to compute the benefit to cost ratio that is found above and in the discussions of Plans 1, 3, and 4.

[6]Benefits were estimated for protection of three specific areas up to the 20-year event. Benefits for 50 percent of freeboard were included where appropriate.

IV. CONCLUSIONS AND RECOMMENDATIONS

The five alternatives that were formulated for this project attempted to be responsive to the need for flood relief in the City of Brockton as well as to the city's economic development, water supply needs, recreation issues, and public safety. In lieu of an economically justified alternative for flood control, a three pronged course of action is recommended to the community.

1. Strict zoning and land use controls should be maintained throughout the entire watershed area. Further development of the Lovett Brook watershed area should be discouraged. Reduction to the area of wetlands and permeable areas will exacerbate an already precarious flood situation due to the restricted channels downstream.

2. The ongoing program of bridge replacements should continue. The prioritization of downstream improvements is sound. Aside from bridges, certain key restrictions should be addressed. Lowering the invert of Salisbury Brook to conform to the culvert entrance downstream from Newbury Street and removal of the concrete conduit upstream from Moraine Street would reduce backwater from the lower flood stages in those immediate areas. A program for more frequent general maintenance of the stream should be established. This should include regular removal of trash and debris as well as brush cutting alongside the channel. Local funds should be allocated for this maintenance on an annual basis.

3. All of the residents in the flood plain should be made aware of the availability of flood insurance through the National Flood Insurance Program. The susceptibility of individual dwellings to flood damages will vary, however this program can provide enough flexibility to satisfy most homeowners' appraisals of their needs.

V. ACKNOWLEDGMENT

The Corps of Engineers would like to recognize the assistance of the city of Brockton Mayor's Office, the Office of the City Planner, the Conservation Commission, the Department of Public Works, and the Department of Parks and Recreation, all of whom made important contributions during the preparation of this report.

Appendices

Appendix A - Public Correspondence Record

Appendix B - Hydrologic Information

Appendix C - Construction Cost Estimates for Plans 1, 3, and 4

Appendix A Public Correspondence Record

Item 1 - Letter to Department of Environmental Management from Corps of Engineers dated 2-9-88

Item 2 - Memo to Office of Congressman Donnelly from Corps of Engineers

Item 3 - Letter to Corps of Engineers from Brockton Conservation Commission dated 4-1-88

Item 4 - Letter to Corps of Engineers from Brockton Mayor's Office dated 5-2-88

Item 5 - Letter to Corps of Engineers from Brockton Conservation Commission dated 5-5-88

Item 6 - Letter to Brockton City Planner from Corps of Engineers date 5-25-88

Item 7 - Letter to Corps of Engineers from Brockton Conservation Commission dated 7-7-88

Item 8 - Letter to Corps of Engineers from Brockton City planner dated 7-15-88

Item 9 - Letter to Corps of Engineers from Soil Conservation Service dated 7-27-88

Item 10- Letter to Corps of Engineers from Brockton City Planner dated 8-11-88

Item 11- Memo to Corps of Engineers from Brockton Conservation Commission dated 9-2-88

Item 12- Letter to Corps of Engineers from Brockton Conservation Commission dated 9-14-88

SWAINE/lc/7532

February 9, 1988

Planning Division
Plan Formulation Branch

Mr. Jack Hannon
Director, Division of Waterways
Department of Environmental Management
100 Cambridge Street, 19th Floor
Boston, Massachusetts 02202

Dear Mr. Hannon:

As part of the Water Resources Development Act of 1986, authorization to study the potential for flood damage reduction, water supply and allied purposes has been included for Brockton, Massachusetts. However, feasibility study must be cost shared equally with non-Federal interests.

At this time we do not know the exact needs and desires of local interests for water resource development in Brockton. In this regard we would like to meet with you or a State designee who could be a point of contact for the initial coordination. Our objective is to develop a Feasibility Cost Sharing Agreement (FCSA), including a Scope of Services (SOS) to determine the best implementable solution(s).

Mr. William Swaine of my staff will contact you within the next week or two to arrange for a meeting, or if you would prefer, you can contact Mr. Swaine at (617) 647-8532.

Sincerely,

Joseph L. Ignazio
Chief, Planning Division

cc:
Mr. Swaine
Reading File
Plan Div Files

MEMORANDUM FOR: MR. JOE ROWAN
OFFICE OF CONG. BRIAN DONNELLY

I hope the following will explain our interpretation of the Water Resources Development Act of 1986 as it applies to the Brockton study.

Section 105(b) of the Act (Enclosure 1) states that the Corps of Engineers shall not initiate any planning or engineering (Feasibility Study) until non-Federal interests agree by contract to contribute 50 percent of the cost of planning and engineering.

We currently have Federal funds to determine the cost of the feasibility study and to prepare a cost sharing agreement. Our current effort will develop a more accurate estimate for preparing the feasibility report. Although I do not have any estimate of the total cost of this effort at this time, I would guess that it could be in the range of $300,000 to $500,000. This would include all design, hydrologic, economic and environmental investigations. Therefore, this would require $150,000 to $250,000 in city/State funds. The feasibility report would be based on the desired improvement by the citizens of Brockton.

Enclosure 2 states that a total cost of $1,500,000 is available for planning, engineering and design. As a rough estimate, we would assume up to $500,000 for planning and engineering (50%-50% cost sharing) and up to $1,000,000 for design (most likely a 75% Federal - 25% non-Federal cost sharing for flood control only).

As I explained on the phone, we still have two very important constraints that may make it undesirable for the city/State to share in the Feasibility Report costs. They include:

(1) Unfavorable benefit-to-cost ratio from the previous Section 205 flood control study.

(2) Current local drainage criteria of 800 cubic feet per second discharge for the 10-year flood event which would preclude Corps construction along Salisbury Brook at this time. However, this policy may be revised in the future.

I hope the foregoing explains some of our problems. We hope to clarify some of these issues when we meet with Brockton officials within the next few weeks. If you have further questions, please call me at (617) 647-8532.

Brockton Conservation Commission

CITY HALL, BROCKTON, MASSACHUSETTS 02401
CAROLINE STONE, EXECUTIVE SECRETARY 580-~~1100, EXT. 155~~ 7167

April 1, 1988

To: Bill Swaine

From: Caroline Stone CS

RE: Salisbury Brook/Salisbury Plain River
Report from: Lally Associates

Enclosed is a copy of the Report prepared in 1984 by Lally Associates. Please pardon the delay in forwarding the report to you. Unfortunately my File Copy had disappeared and I had to have another Department make me a copy. I hope the information will be useful in evaluating the future action for Reclamation Work.

We have requested an update of our pending application with Rivers and Harbors. It is my understanding that Soil Conservation Service Representatives, Stephen Claughton, and Dennis Verdi; have been in contact with your office since they met with some of us here at City Hall on March 9. We look forward to hearing from you soon about a date for a meeting to coordinate the various aspects of the project. We will then consider how much funding the City can consider appropriating during the coming Fiscal Year.

If you have any questions, please give me a call. I am also enclosing a Summary Sheet stating projects which are in progress and being contemplated to begin in the near future for your reference.

I look forward to hearing from you in the near future.

Encl.
Report-- Lally Associates
Summary Sheet

City of Brockton Massachusetts
Office of the Mayor
Carl D. Pitaro, MAYOR, CITY HALL, BROCKTON, MA 02401 617/580-1100

May 2, 1988

Colonel Thomas Rhen
Division Engineer
Department of the Army Corp of Engineers
424 Trapelo Road
Waltham, MA 02154

Dear Colonel Rhen:

Please consider this our letter of intent to cost share in the Salisbury River Flood Control Project. This is a project critical to the interest of the City and is an attempt to alleviate a flooding problem in sections of our City.

We have been working with F. William Swaine of your department in our efforts to have this project prioritized by your agency and there is a new cost benefit analysis underway which hopefully will expedite this project.

Any assistance you can give us would be appreciated.

Sincerely,

Carl D. Pitaro
Mayor

CDP/ec

Brockton Conservation Commission

CITY HALL, BROCKTON, MASSACHUSETTS 02401

CAROLINE STONE, EXECUTIVE SECRETARY 580-7167

May 5, 1988

To: David Larson

From: Caroline Stone CS

RE: Soil Conservtion Service Study
Salisbury Brook--- 1985

Enclosed is a copy of the Soil Conservation Service Report. We have not received a Final Copy. I believe your office has been in contact with the staff from Amherst who met with some us here at City Hall in March. Marc MacQueen, who is at the Middleboro Office was also at that meeting.

If you have any questions on this report or other aspects of the project, please call me at the number listed above.

We look forward to working with you on the study.

Encl.--1

May 25, 1988

Planning Division
Plan Formulation Branch

Ms. Nancy Stack-Savoie
City Planning Office
Brockton City Hall
Brockton, Massachusetts 02401

Dear Ms. Stack-Savoie:

As a follow up to your meeting on April 26 with Corps personnel regarding the Brockton Flood Control Study, we are requesting flood damage information that will supplement previous evaluations. This will insure an accurate assessment of economic benefits during our current preliminary analysis.

Your coordination and assistance in gathering the following information would be greatly appreciated:

(1) Dates and severity of past flood events

(2) Emergency costs due to flooding borne by the city. Some examples are: Pumping, sandbagging, evacuation and shelter operations, labor costs for police, fire department, and D.P.W. overtime.

(3) Clean-up costs borne by the city. Some examples are: street cleaning, removal of channel obstructions created by the flood, repair to streets and bridges.

(4) Emergency and clean-up costs due to flooding borne by private interests if available.

(5) Physical damages to property; i.e. damages to dwellings and their contents.

(6) Other losses; for example: cost of lost production (firms forced to close by flooding), interruption of public transportation services, cost for restoration of utilities.

(7) Summary of 1983 damage study by Brockton Conservation Commission.

Documentation of the dates on which these costs were incurred is also important so the Corps can correlate those dates with records of meteorological events.

If you have any questions regarding this request, or any other aspects of the Corps' investigation, please contact Mr. David Larsen at (617) 647-8113.

Sincerely,

Joseph L. Ignazio
Chief, Planning Division

Brockton Conservation Commission

CITY HALL, BROCKTON, MASSACHUSETTS 02401
CAROLINE STONE, EXECUTIVE SECRETARY 580-7167

July 7, 1988

To: David Lawson

From: Caroline Stone

RE: Salisbury Brook/Salisbury Plain River Data

Attached are copies of the Publicity for the June 30, 1988 Meeting.

You will also find copies of the questionnaires returned from the 1983 Survey in two catagories. There is a Summary Sheet giving FEMA Data on the number of Claims paid in general in the City. You may be able to obtain more specific location data by calling FEMA Region I Office directly.

The Package of documentation submitted by the Walkover Club is also enclosed.

We are still making contacts to obtain additional information on damages.

I will be in contact with you again in the next couple of weeks.

We hope to forward other information from individuals and the City Law Department Claims File. The Law Department Secretary cannot begin to search for the data until next week.

Encl.
- Walkover Club Package
- 2 Sets Questionnaires
- FEMA Summary
- Publicity for 6/30/88 Meeting

City of Brockton
Office of the City Planner
City Hall
Brockton, Massachusetts 02401
(617) 580-1100, Ext. 186

Nancy Stack Savoie
City Planner

July 15, 1988

Mr. David Larson
Army Corps of Engineers
424 Trapelo Road
Waltham, MA 02254

Attn: Planning Division

RE: Brockton, Massachusetts

Dear Mr. Larson:

The Office of the City Planner has encountered some difficulty in gathering some of the data needed for your Benefit/Cost Analysis.

I with to inform you that this information will be forwarded to you no later than July 29, 1988. This extension will permit us to contact city officials and businesses who have been on vacation.

Thank you for your anticipated cooperation.

Yours truly,

Nancy Stack Savoie

NANCY STACK SAVOIE
CITY PLANNER

NSS/ds

United States Department of Agriculture
Soil Conservation Service
451 West Street
Amherst, MA 01002
Tel. (413) 256-0441

July 27, 1988

Mr. William Lurson
Planning Division
New England Division
Corps of Engineers
Dept. of the Army
424 Trapelo Road
Waltham, MA 02254-9149

Re: BAP - Basin and Area Planning, Salisbury Brook, Brockton, MA.

Dear Mr. Lurson:

Enclosed for your information are the flood routing results for Lovett and Beaver Brooks in the Salisbury Brook Watershed in Brockton, MA.

Please contact Dennis Verdi if you have any questions on this information.

Sincerely,

Carl J. Gustafson

CARL J. GUSTAFSON
State Conservation Engineer

Enclosures

City of Brockton
Office of the City Planner
City Hall
Brockton, Massachusetts 02401
(617) 580-1100, Ext. 186

Nancy Stack Savoie
City Planner

TO: David Larsen, Army Corps of Engineers

FROM: Nancy Stack Savoie, City Planner

DATE: August 11, 1988

RE: Salisbury Plain River - Flooding; Brockton, MA

Enclosed please find documentation relative to damages and costs incurred due to the flooding of the Salisbury Plain River. Documentation includes costs borne by the City as well as private citizens and businesses.

List of Exhibits

A - Public Participation

B - Photpgraphic Documentation

C - Costs to City of Brockton

D - Costs to Businesses and Area Residents

Should you have any question, do not hesitate to contact me.

Speed Message

To David Larsen

From Caroline Stone
Brockton Conservation Commission

Subject Salisbury Brook-Salisbury Plain River Study

Date Sept. 2, 1988

Enclosed is another letter from one of the River Abutters in the Perkins Ave. Area which was waiting with my mail when I returned from vacation. It contains good information about the river situation.

The City has also received a Grant for work on the Main St. Bridge. Robert Cyr, Highway Supt., advised me that the Utilities will be relocated as part of the forthcoming project.

Look forward to hearing from you as things progress. If you have any questions, give me a call.

Encl.-1

Signed Caroline Stone

1184

Brockton Conservation Commission

CITY HALL, BROCKTON, MASSACHUSETTS 02401
CAROLINE STONE, EXECUTIVE SECRETARY 580-7167

September 14, 1988

To: David Larsen

From: Caroline Stone CS

RE: Salisbury Brook-Salisbury Plain River Project

The enclosed press coverage about the project which John Dorgan has in progress at Field Park will be of interest to you in working on the Studies. If you have any questions, please contact John Dorgan or myself.

We look forward to working with you this fall as the study project continues.

Appendix B Hydrologic Information

Discharge/Frequency Curves

Stage/Frequency Curve
Salisbury Brook at Belmont Ave.
Salisbury Brook at Newbury St.
Salisbury Plain River at Grove St.
Salisbury Plain River at Perkins Ave.
Salisbury Plain River at Meadow Lane
Salisbury Brook at Belmont Ave.
Modified for Tunnel By-Pass

CENED-ED-WH (CENED-PL-PS/2 Jun 88)
SUBJECT: Salisbury Brook/Salisbury Plain River, Brockton, Massachusetts

TO Chief, Planning Division FROM Acting Chief, Engineering Div. DATE 16 Sep 88 CMT 2 Mr. Yen/mbc/7161

1. General. In response to basic memo the following hydrologic data are forwarded for use during preliminary analysis to study potential flood reduction measures in Brockton.

a. Discharge-frequency curves for various locations in Brockton, Massachusetts on Salisbury Brook and Salisbury Plain River.

b. Stage-frequency curves for the same locations (copies of these curves were hand-carried on 1 September to Mr. Larsen to expedite the process). Locations chosen were those identified by the project manager as having the highest damage potential.

c. Sizing of a bypass conduit for a 100-year discharge between Malvern and Belmont Streets.

d. Assessment of existing reservoir and storage areas in the Brockton study as to their potential to reduce downstream floodflows.

2. Watershed Description. The Salisbury Brook watershed is located in southeastern Massachusetts in the city of Brockton, Plymouth County, and the towns of Avon and Stoughton in Norfolk County. The brook is formed at the confluence of Beaver and Lovett Brooks in Brockton. Beaver Brook has its source in Stoughton, MA and flows in a southeasterly direction into Brockton Reservoir and through a series of ponds until it is joined by Lovett Brook at Ellis Brett Pond to form Salisbury Brook. Salisbury Brook has a total drainage area of 8 square miles and joins Trout Brook forming Salisbury Plain River in central Brockton. Salisbury Plain River then flows into the Mansfield River and ultimately into Taunton River and Narragansett Bay. The lower portion of the watershed is predominantly urban (see attachment 1).

3. Peak Discharge Frequencies. There are no USGS gaging stations on Salisbury Brook or Salisbury Plain River; therefore, gaged streams in the region were analyzed. Peak discharge frequencies were developed from gaged data on Dorchester Brook (drainage area = 4.67 square miles), located adjacent to the Salisbury Brook watershed and East Branch Neponset River in Canton, MA (drainage area = 27.2 square miles), located 5 miles northwest of Brockton. Dorchester Brook and East Branch Neponset River both have similar hydrologic characteristics, i.e., sluggish streams with flat channel and numerous water bodies. Peak annual discharges of both streams were analyzed in a Log Pearson Type III distribution in accordance with guideline in Water Resources Council Bulletin 17B. The results from analysis of 12 years of record on Dorchester Brook were mean log 2.058, standard deviation 0.268, and

computed skew of 0.656. The results of analysis of 33 years of record available for East Branch Neponset River were mean log 2.66, standard deviation 0.25, and computed skew 0.721. Peak discharge frequencies computed at both streams were transferred to the Salisbury Brook and Salisbury Plain River by drainage area ratio to the 0.7 power with the resulting discharges, as transferred from both gages, in close agreement. As a check for reasonableness of the computed discharge frequencies, high watermark estimates of the August 1955, April 1969, and March 1968 flood events were used. These are not precise surveyed high watermarks but were gathered during past Corps studies. These estimates were used along with flood profiles presented in the Brockton Flood Insurance Study, dated September 1978, and prepared by the Soil Conservation Service to assign discharges to these three flood events. Based on these discharge estimates, the 1955 flood had a peak discharge on Salisbury Brook of 800 cfs. Based on the computed discharge frequencies, this flood would represent about a 1 percent chance (100-year) of occurrence. The developed discharge frequency curves with estimated discharges for the three flood events are shown on attachment 2. As can be seen on the developed curves, Salisbury Brook (D.A. = 7 square miles) and Salisbury Plain River (D.A. = 16.4 square miles) have 10 percent (10-year) peak discharges of about 350 and 600 cfs, respectively. Neither location meets current Corps minimum criteria of 800 cfs for the 10-year event under ER 1165-2-21. However, OCE is reviewing the adequacy of this criteria with the possible outcome of lowering the 800 cfs value; therefore, current initial studies will be continued.

4. Stage Frequencies.

a. Existing Conditions. Stage-frequency curves for Salisbury Brook and Salisbury Plain River were developed at several identified locations in Brockton. The curves shown in attachments 3 through 7 were developed based on the adopted discharge frequencies and stage discharge relationships developed from flood profiles presented in the Brockton Flood Insurance Study.

b. Modified Condition. Also shown on the stage-frequency curves are the estimated modifying effects of the channel improvement plan developed by Fenton Keyes Associates in 1975. It is noted that precise information and detailed backup data and analysis for this plan are not available and modifications shown on the curves are estimates from modified profiles developed during Fenton Keyes studies. If this plan indicates economic feasibility, detailed studies including surveys and backwater analysis would be required.

5. Bypass Conduit. Salisbury Brook passes under numerous bridge openings and is enclosed within conduits for much of its length. In addition, the channel is extremely confined and encroached upon in many

areas. These factors make any channel improvement work extremely difficult. As an alternative, a bypass conduit was investigated. Flows could be intercepted at Malvern Street and conveyed in a conduit through a low area reentering the brook at Elm Street as shown on attachment 1. Total length of the conduit would be about 7,000 feet. Assuming an existing brook capacity of 250 cfs, to provide a one percent chance (100-year) level of protection, a conduit with 550 cfs capacity would be required. A 9 by 8 foot or equivalent sized concrete conduit would convey 550 cfs with a total hydraulic head loss of about 20 feet assuming a Manning's "n" coefficient of 0.015. Modifications to stage-frequency curves due to the bypass conduit are shown on attachment 8. The bypass alignment was determined by the project manager and was developed in an effort to minimize excavation. It is noted that hydraulically the numerous bends and angles would cause increased head losses and if the project indicates any economic feasibility, final alignment could be modified.

6. Existing Reservoir and Storage Areas

a. General. Beaver Brook, located in the Salisbury Brook headwaters, flows through several reservoirs and ponds. Two of the larger ponds, Brockton and Waldo, are being considered, by the city of Brockton, for water supply use. It was requested that these ponds be investigated as to their potential to reduce downstream floodflows.

b. Pertinent Data. Pertinent data on all ponds are listed on the attached table.

c. Surcharge Storage. As can be noted in the table, the only impoundments that provide significant surcharge storage are Brockton Reservoir and Waldo Lake; drainage areas of the two reservoirs are 3.0 and 3.2 square miles, respectively. One foot of surcharge at Brockton Reservoir and Waldo Lake represents a total storage capacity of about 1 inch of runoff with the resulting outflow at Waldo Lake of approximately 40 cfs (12 csm). Therefore, each foot of surcharge represents a significant storage volume with a relatively small outflow. The lower ponds, (Upper and Lower Porter, Thirty-Acre, Ellis Brett, and Cross) have relatively small surface areas and little surcharge storage.

d. Contribution to Floodflows. Past Corps studies indicate that peak discharges along Salisbury Brook are caused primarily by runoff from local urban areas and Lovett Brook. A cursory analysis of the 100-year frequency flood event shows that the peak discharge at Newbury Street was caused primarily by runoff downstream of the ponds. Contribution of the Brockton Reservoir system (Brockton Reservoir to Thirty-Acre Pond) to peak flows was only about 5 percent of the total at Newbury Street. Peak outflow from the reservoir system occurred over 10 hours after downstream peak floodflows had subsided.

e. Summary/Conclusions. Based on the above analysis, it appears as though the Brockton Reservoir system is currently functioning to reduce and delay peak outflows on a self-regulating basis. Increasing the effectiveness of surcharge storage at Brockton and Waldo Ponds is limited due to the small total surcharge storage available (4 and 3.5 feet, respectively). Any modification to the outlet structures to utilize additional surcharge would result in less freeboard during flood conditions and increased risk of dam overtopping. Also development of guide curves to allow the reservoirs to be drawn down prior to flooding was not explored due to the relatively small contribution (5 percent) of reservoir outflows to peak discharges along Salisbury Brook.

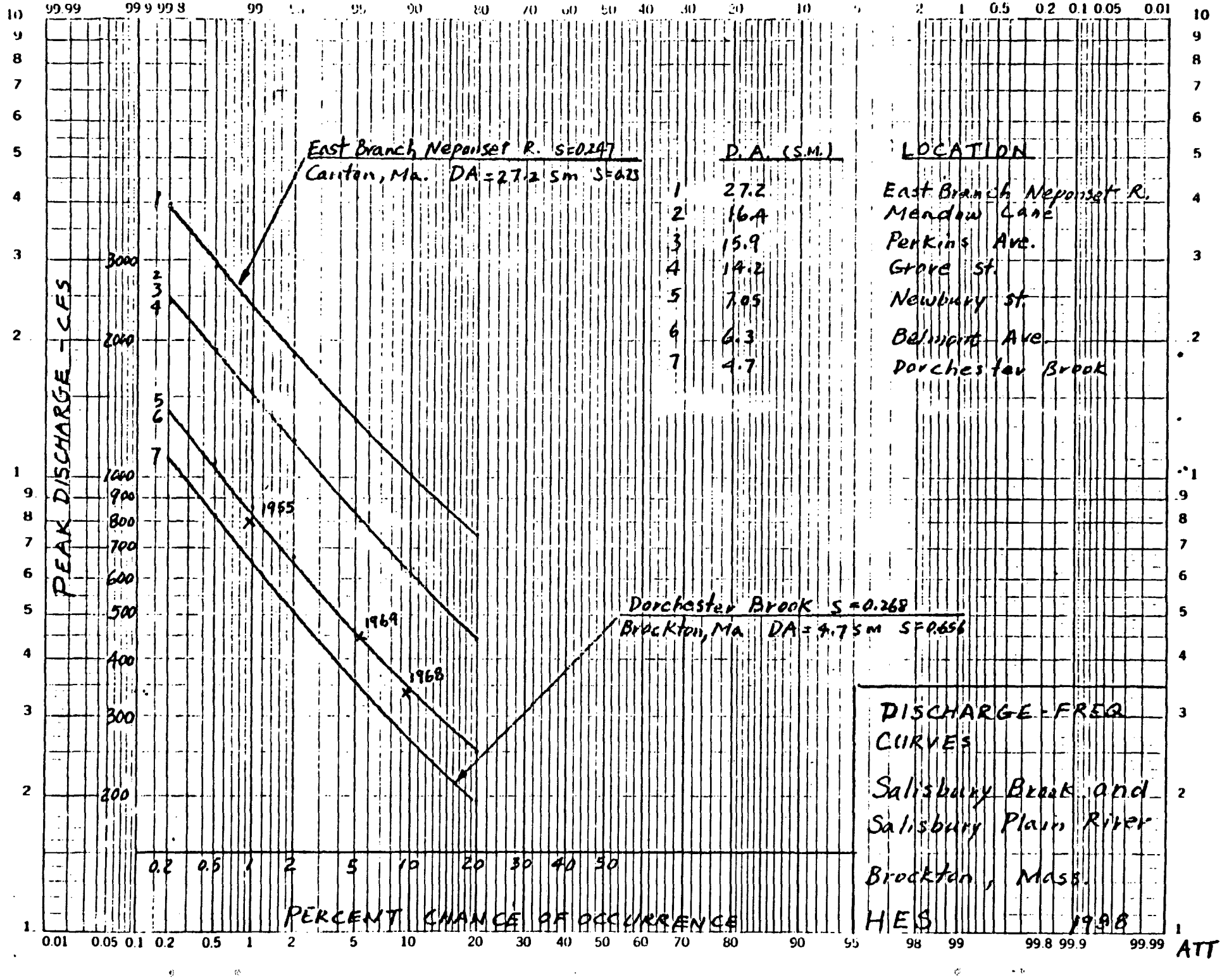
8 Atchs

ROBERT L. HARRINGTON
Acting Chief, Engineering Division

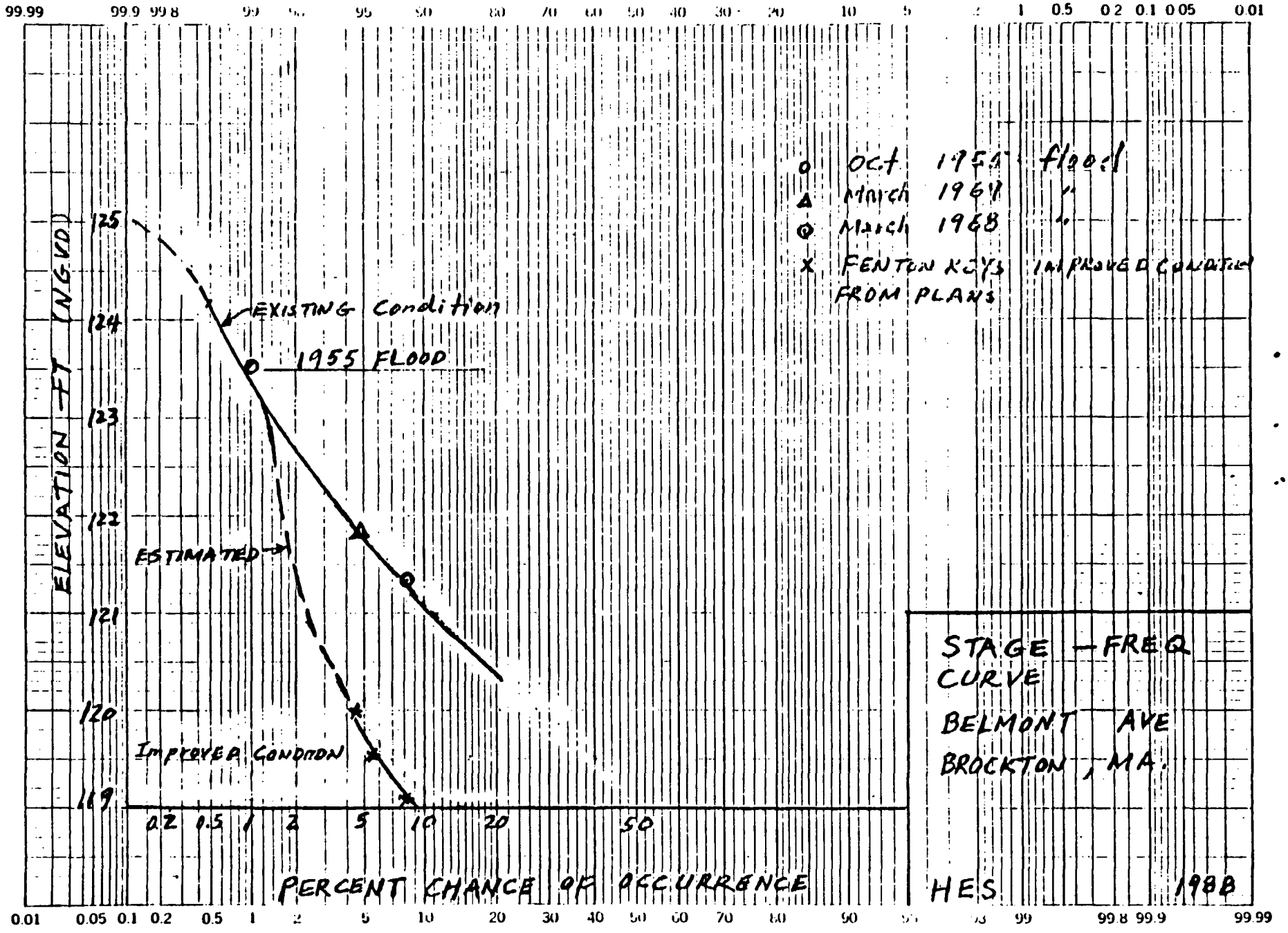
CF:
Mr. Yen - 115N
Engr Div Files - 112S


HOLBROOK
High School
AVON
Pinnacle
Curtis Cem
Standpipe
Avon
St Michaels Cem
Brookville
HOLBROOK
Sand and Gravel Pits
Wendell Cem
Drive-in Theater
NORFOLK CO
PLYMOUTH CO
Sand and Gravel Pit
Sand and Gravel
Brockton Reservoir
Waldo Lake
D PARK
Upper Porter Pond
Lower Porter Pond
Montello
Pumping Station
Fire Station
Water Sch
Franklin Sch
North Jr High Sch
Golf Course
INTERCHANGE 28
Melrose Cemetery
Armory
Naval Reserve
Calvary Cemetery
St Patricks Cem
BROCKTON
Brockton Heights
City Hall
Union Cemetery
East High Sch
BY PASS AREA
West Jr High Sch
Thorny Lea Golf Club
Radio Towers
Winters Corner
TORREY
Edgar Sch
BELMONT
US VETERANS ADMINISTRATION HOSPITAL
Clifton Heights
Brook
Salisbury
Trout Brook
A
B
C
D
E

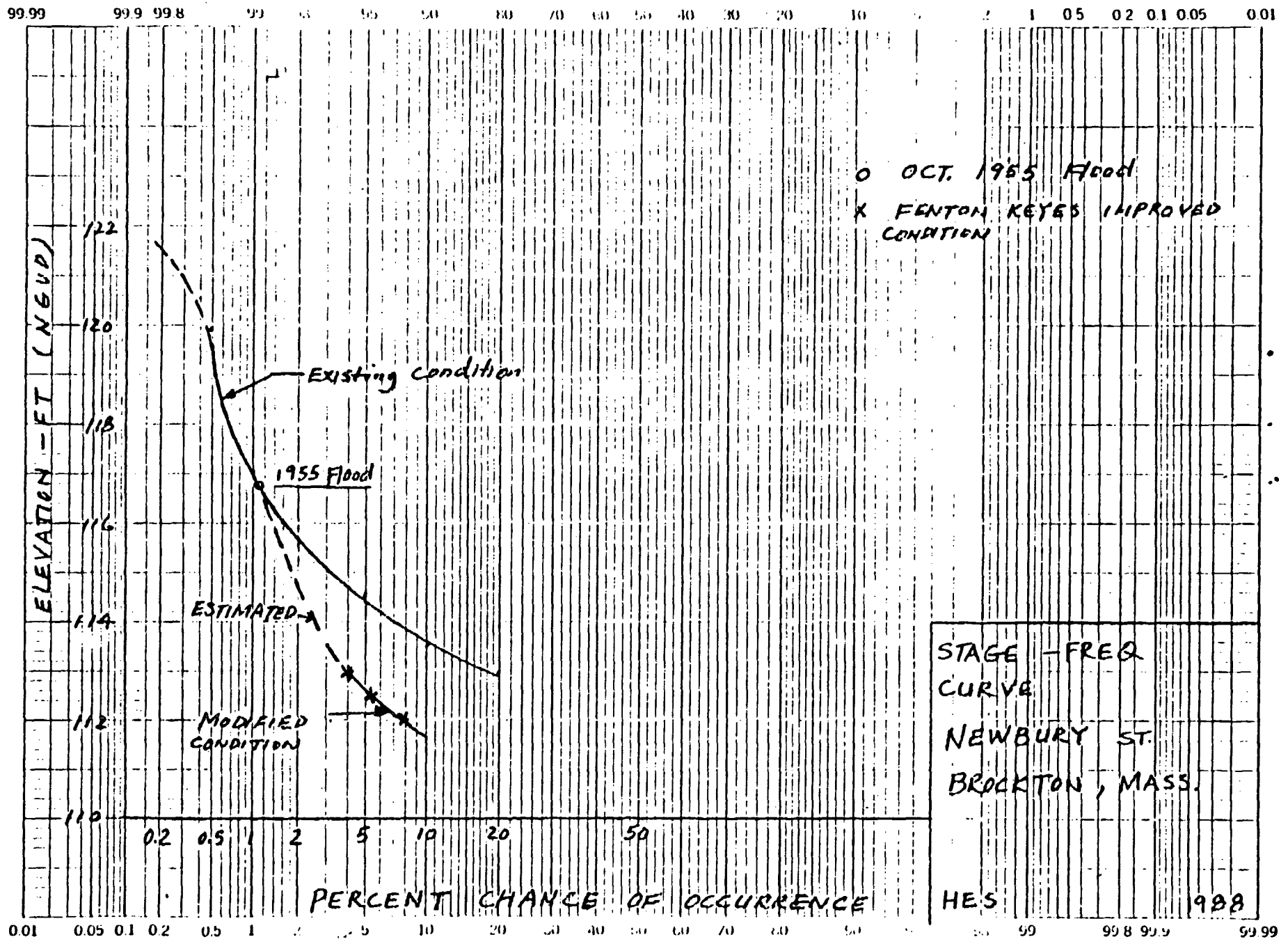
ATT # 1


East Branch Nepoiset R. S=0.247
Canton, Ma. DA=27.2 sm S=023
Dorchester Brook S=0.268
Brockton, Ma DA=4.75 sm S=0.656
1955
1969
1968
PEAK DISCHARGE - CFS
PERCENT CHANCE OF OCCURRENCE
D.A. (S.M.)
1 27.2
2 16.4
3 15.9
4 14.2
5 7.05
6 6.3
7 4.7
LOCATION
East Branch Nepoiset R.
Meadow Lane
Perkins Ave.
Grove St.
Newbury St.
Belmont Ave.
Dorchester Brook
DISCHARGE-FREQ CURVES
Salisbury Brook and Salisbury Plain River
Brockton, Mass.
HES 1968

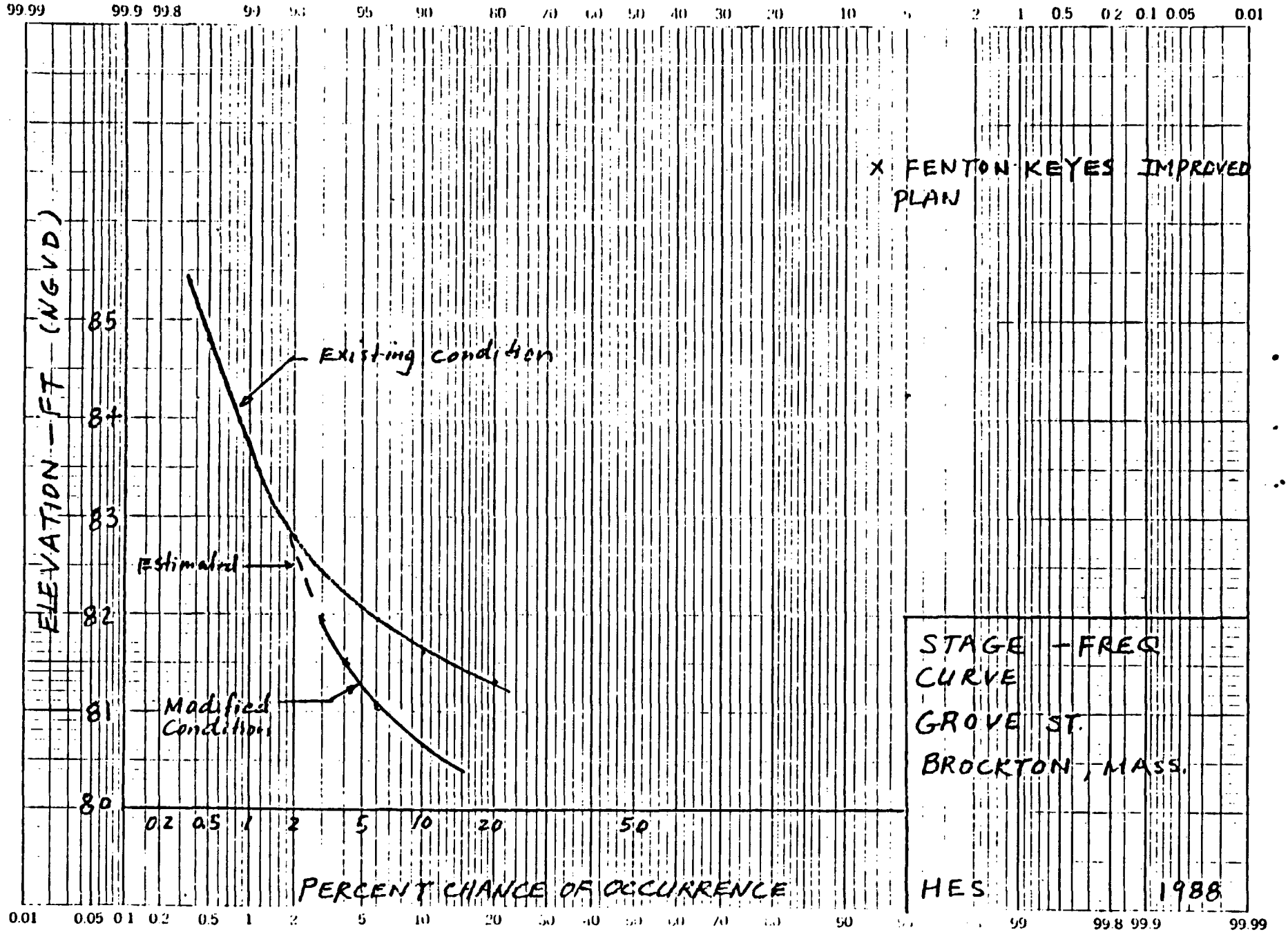
ATT #2


99.99 99.9 99.8 99 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
ELEVATION - FT (NGVD)
125
124
123
122
121
120
119
EXISTING Condition
1955 FLOOD
ESTIMATED
IMPROVED CONDITION
0.2 0.5 1 2 5 10 20 50
PERCENT CHANCE OF OCCURRENCE
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9 99.99
o Oct 1954 flood
Δ March 1968 "
□ March 1968 "
x FENTON KEYS IMPROVED CONDITION FROM PLANS
STAGE - FREQ CURVE
BELMONT AVE
BROCKTON, MA.
HES 1988

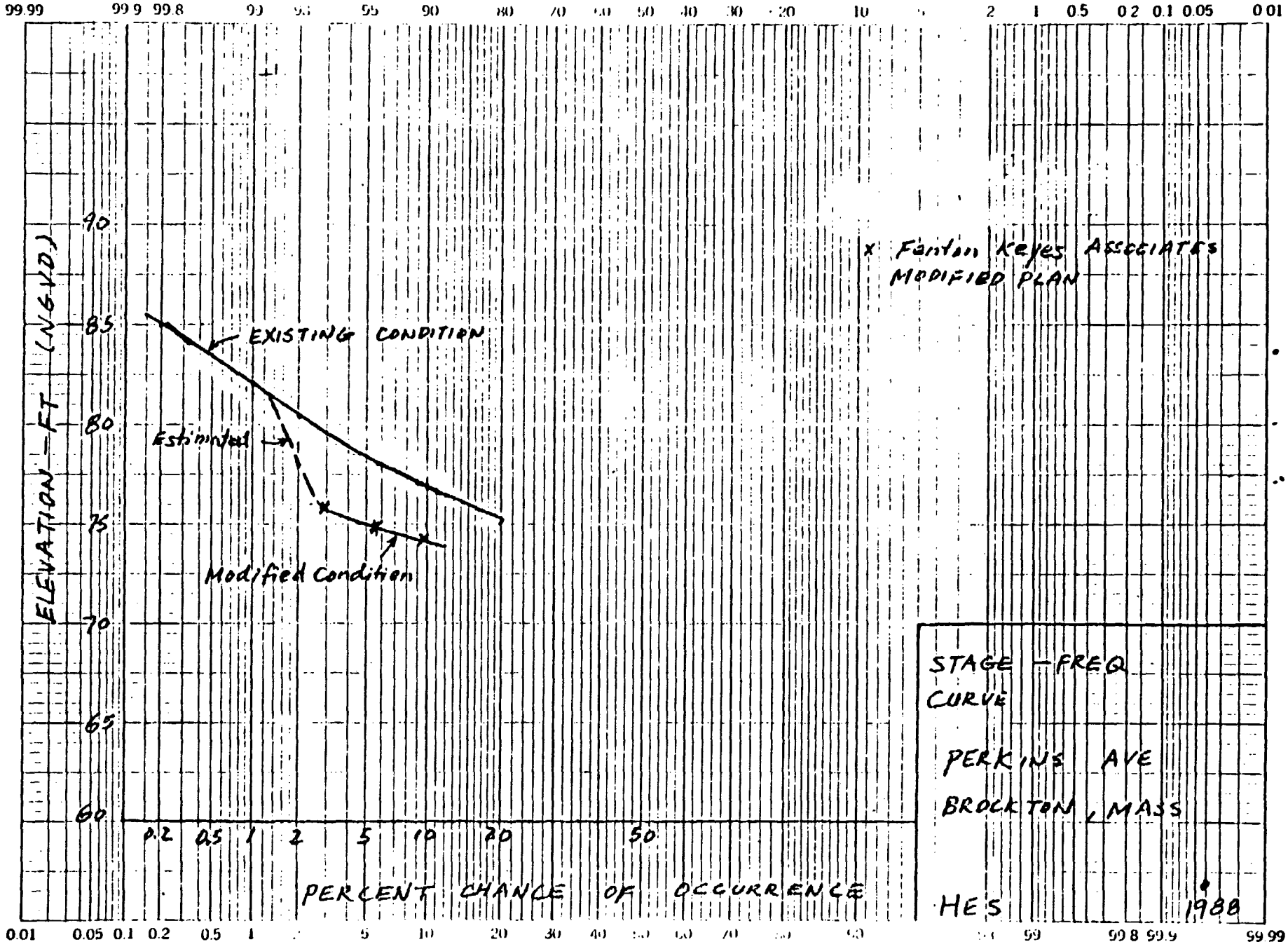
ATT #3


99.99 99.9 99.8 99 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
ELEVATION - FT (NGVD)
122
120
118
116
114
112
110
Existing condition
1955 Flood
ESTIMATED
MODIFIED CONDITION
0.2 0.5 1 2 5 10 20 50
PERCENT CHANCE OF OCCURRENCE
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 99 99.8 99.9 99.99
o OCT. 1955 Flood
x FENTON KEYES IMPROVED CONDITION
STAGE - FREQ CURVE
NEWBURY ST.
BROCKTON, MASS.
HES 988

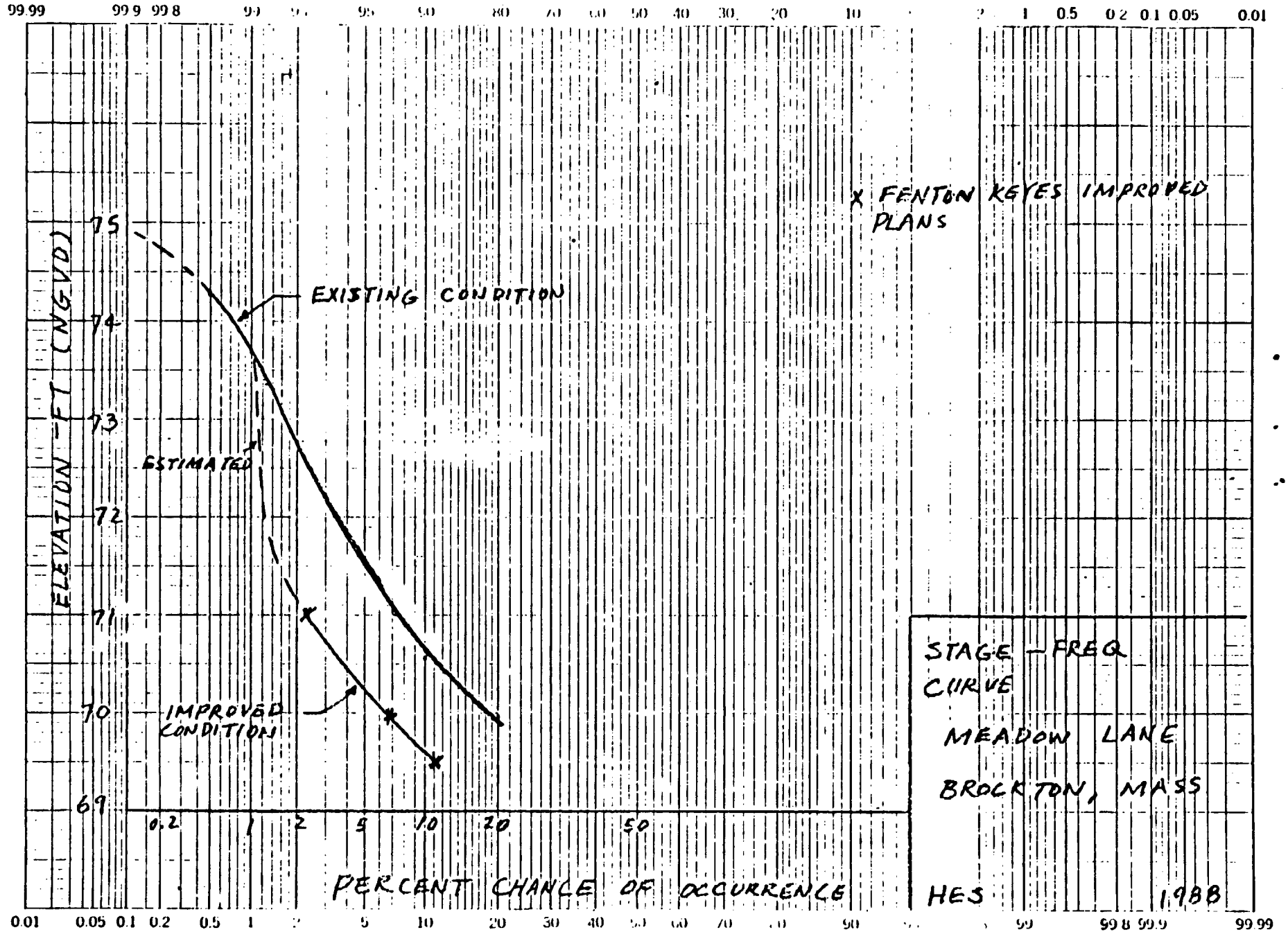
ATT #4


99.99 99.9 99.8 99 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
ELEVATION — FT — (NGVD)
85
84
83
82
81
80
X FENTON KEYES IMPROVED PLAN
Existing condition
Estimated
Modified Condition
STAGE — FREQ CURVE
GROVE ST.
BROCKTON, MASS.
HES 1988
0.2 0.5 1 2 5 10 20 50
PERCENT CHANCE OF OCCURRENCE
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 50 80 90 95 99 99.8 99.9 99.99

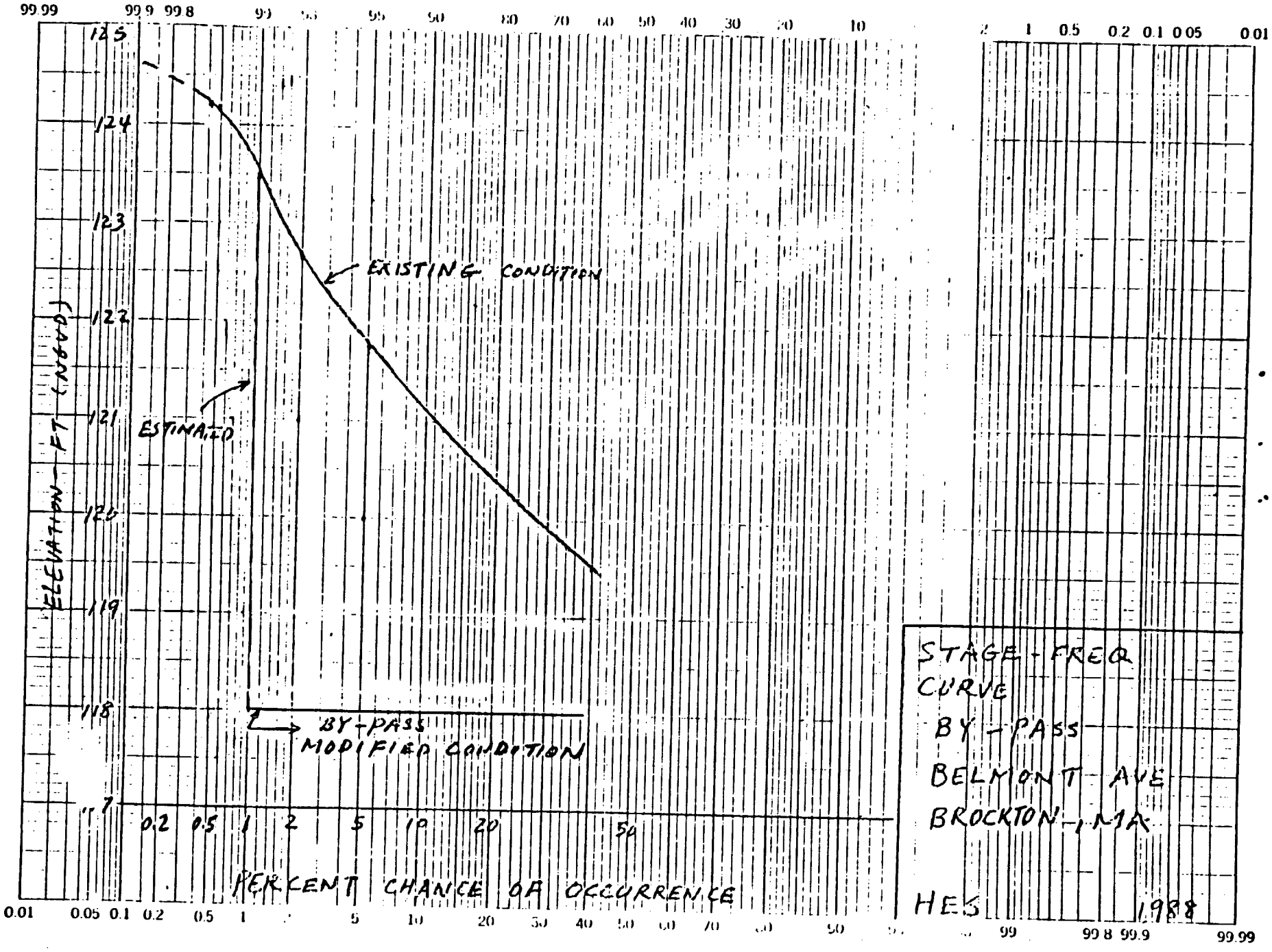
ATT #5


99.99 99.9 99.8 99 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
ELEVATION — FT (NGVD)
90
85
80
75
70
65
60
EXISTING CONDITION
Estimated
Modified Condition
x Fantan Keyes Associates
MODIFIED PLAN
STAGE — FREQ
CURVE
PERKINS AVE
BROCKTON, MASS
HES
1988
0.2 0.5 1 2 5 10 20 50
PERCENT CHANCE OF OCCURRENCE
0.01 0.05 0.1 0.2 0.5 1 5 10 20 30 40 50 60 70 90 95 99 99.8 99.9 99.99

ATT #6


99.99 99.9 99.8 99 95 90 80 70 60 50 40 30 20 10 2 1 0.5 0.2 0.1 0.05 0.01
ELEVATION - FT (NGVD)
75
74
73
72
71
70
69
X FENTON KEYES IMPROVED PLANS
EXISTING CONDITION
ESTIMATED
IMPROVED CONDITION
0.2 1 2 5 10 20 50
PERCENT CHANCE OF OCCURRENCE
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9 99.99
STAGE - FREQ CURVE
MEADOW LANE
BROCKTON, MASS
HES 1988

ATT # 7


ELEVATION - FT (NGVD)
125
124
123
122
121
120
119
118
117
EXISTING CONDITION
ESTIMATED
BY-PASS MODIFIED CONDITION
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9 99.99
PERCENT CHANCE OF OCCURRENCE
STAGE - FREQ CURVE
BY - PASS
BELMONT AVE
BROCKTON - MA
HES 1988

ATT # B

Appendix C Construction Cost Estimates for Plans 1, 3, and 4

Construction Cost Estimate for Plan 1
Construction Cost Estimate for Plan 3
Construction Cost Estimate for Plan 4

Construction Cost Estimate for Plan 1, Comprehensive Flood Protection
(Updated Corps Plan from 1975)

Description	Estimated Quantity	Unit	Unit Price	Estimated Amount
Remove Plate Girder Bridge @ Churchill Linen Co.	1	Job	L.S.	2,500
Flood Walls				
Right Bank, between Perkins Ave. and Forest St.	375	L.F.	$450	169,000
Left Bank, between Perkins Ave. and Forest St.	60	L.F.	$450	27,000
Right Bank, upstream of Perkins Ave.	50	L.F.	$450	22,500
Dikes upstream of Perkins Ave.	870	L.F.	$190	165,300
New Culvert behind Y.M.C.A.	140	L.F.	$1500	210,000
"U"Channel between Newbury St. and Culvert Entrance behind Courthouse	225	L.F.	$900	202,500
New Conduit along Ellsworth St.	535	L.F.	$1250	669,000
"U"Channel between Ash St. and Belmont Ave.	670	L.F.	$1050	703,500
Floodwalls Right and Left Banks between Spring St. and Belmont Ave.	1290	L.F.	$450	580,500
Remove Concrete Culvert upstream of Morraine Street	1	Job	L.S.	7,000
Remove Concrete Deck upstream of Prospect Street	1	Job	L.S.	9,500
New Bridge at Perkins Ave.	1750	S.F.	$200	350,000
New Bridge at Belmont Ave.	1250	S.F.	$200	250,000
New Bridge at Ash St.	1350	S.F.	$200	270,000
New Bridge at Pleasant St.	1350	S.F.	$200	270,000
Utility Relocations	1	Job	L.S.	417,000
SUBTOTAL				4,325,300
Construction Contingency	15%			648,800
SUBTOTAL				4,974,100
Engineering and Design	15%			746,100
TOTAL				5,720,200

Construction Cost Estimate for Plan 3, Tunnel By-Pass with Miscellaneous Channel Improvements

Description	Estimated Quantity	Unit	Unit Price	Estimated Amount
By-Pass Culvert (includes all associated costs and contingencies)	6250	L.F.	$1,032	$6,448,200
Dikes upstream of Perkins Ave.	870	L.F.	$190	165,300
Floodwalls				
Right bank, between Perkins Ave. and Forest St.	375	L.F.	$450	169,000
Left bank, between Perkins Ave. and Forest St.	60	L.F.	$450	27,000
Right bank, upstream of Perkins Ave.	50	L.F.	$450	22,500
TOTAL				$6,832,000

Construction Cost Estimate for Plan 4
20 Year Selective Protection Program

Description	Estimated Quantity	Unit	Unit Price	Estimated Amount
Dikes upstream of Perkins Ave.				
Right Bank	130	L.F.	$ 131	$ 17,000
Left Bank around Walkover Club	700	L.F.	$ 250	$ 175,000
Flood Walls Between Perkins Ave. and Forest St. (for both banks)	480	L.F.	$1150	$ 551,000
Cap existing retaining wall downstream from Perkins Ave.	300	L.F.	$ 50	$ 15,000
Replace retaining wall sections downstream from Foreest St. (for both banks)	90	L.F.	$1180	$ 106,000
"U"Channel between Newbury St. and culvert entrance behind Courthouse	225	L.F.	$ 900	$ 202,500
Floodwalls between Belmont Ave. and Spring St. (for both banks)	1290	L.F.	$ 450	$ 580,500
Floodwalls between Ash St. and Belmont Ave.	1340	L.F.	$ 450	$ 603,000
SUBTOTAL				$2,250,000
Construction Contingency	15%			337,500
SUBTOTAL				$2,587,500
Engineering and Design	15%			338,100
TOTAL				$2,975,600